Air & Space

National Air & Space Museum
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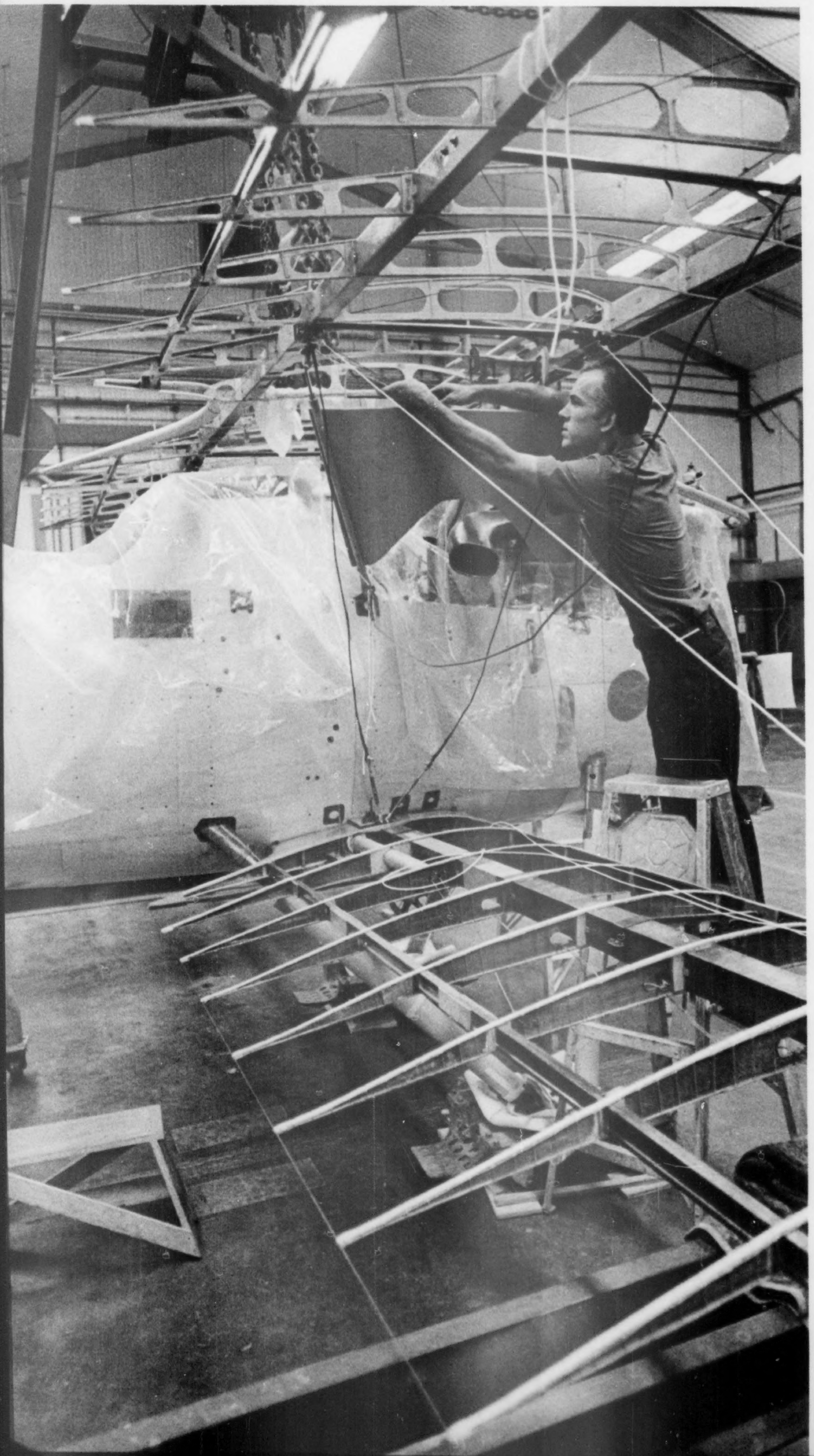

# MEETING THE CHALLENGE OF RESTORATION

is a daily labor of love at the National Air and Space Museum's Paul E. Garber Preservation, Restoration, and Storage Facility in Suitland, Maryland. Here, where a "no-frills" museum houses the world's largest single collection of aircraft, spacecraft, and flight-related objects, a staff of highly-skilled craftsmen patiently restores an average of four vintage aircraft per year. Preserving aviation technology—not just the objects *per se*, but the techniques used in their construction—is the goal of this unique facility.

In this photo, Museum Technician Garry Cline carefully determines the dimensions of missing cabane struts during restoration of NASM's Albatros D. Va. The various types of the Albatros were the most widely manufactured and used —and among the most important— of German World War I fighters. (Manfred von Richthofen, the famous "Red Baron," scored most of his 80 victories in Albatros fighters, not in his red Fokker triplane, as legend implies.) NASM curators and the Garber Facility staff, undertaking their most difficult and ambitious project to date, spent 8629 manhours restoring this historically significant aircraft, one of only two known surviving examples of the type. More, pages 3-5.

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*Air & Space*, a mini-magazine for educators, is published four times during the year, September through May, as an outreach of the National Air and Space Museum, Smithsonian Institution, Washington, D.C.

*Air & Space* combines information from many sources for a condensed overview of the history, science, technology, and social impact of selected aviation and space subjects.

**Air & Space** Registration
Current recipients of *Air & Space* who did not return the *blue* registration renewal card bound into the Fall 1980 issue must fill out the *green* card bound into this issue and return it by January 10, 1980 to *Air & Space*, Room P-700, Education Services Division, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560.

For changes or corrections of address, write the correct address in the appropriate place on the card. Readers receiving unwanted duplicates should return only one renewal card.

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*Air & Space* may be freely photocopied for classroom use. Commercial interests and other publications wishing to reprint material should mail request (address on back cover).

MUSEUM HOURS
Until March 31, the Museum will be open from 10 a.m. to 5:30 p.m.; starting April 1, Museum hours will be 10 a.m. to 9 p.m. The Museum is open to the public every day of the year except Christmas.

**For brevity, the National Air and Space Museum is often referred to in these pages as NASM. The National Aeronautics and Space Administration is NASA.**

# BRIEFING

## *Space program doldrums*

Noel W. Hinners
Director, NASM

These are trying times for proponents of space exploration. To judge from news accounts, little seems to be going right with the U.S. space program. The cost of the Space Shuttle continues to rise as technical problems occur—or recur—with concomitant slips in schedule. These delays have caused the only U.S. planetary mission under development, the Galileo orbiter/probe of Jupiter, to be rescheduled from a 1982 single launch to a more expensive dual 1984 launch (see May-June 1980 *Air & Space*, page 3). Landsat-D, the follow-on Earth resources satellite, also has increased in cost, slipped in schedule, and may not carry desired new second-generation remote sensing instrumentation. National pessimism about our space program is heightened by the small number of new missions under development for the 1980s and beyond, and by the dismal national economy. These factors, say space exploration advocates, will result in a deleterious interruption of the U.S. space program.

Such U.S. spacecraft as the Vikings, Voyagers (the first of which will encounter Saturn in November 1980), High Energy Astronomy Observatories, Solar Maximum, Magsat, Heat Capacity Mapping Mission, and numerous commercial communications satellites have been extremely successful. These successes tend to be overlooked or, at the least, dismissed with the comment that these programs were initiated many years ago and that we are living off the labors of the past.

Cycles of ups and downs characterize most endeavors. These ups and downs ought to be viewed with a long-term perspective and a dogged resolve that what one is doing is good and necessary. Only in that way will one push ahead despite periods of adversity.

We tend to forget that most projects of major scope and importance need decades to get under way. Columbus lobbied for his transatlantic voyages as early as 1484 in Portugal. A year later, after King John told him to fund the voyages himself, Columbus moved his campaign to Spain. There he cooled his heels for seven years while Ferdinand and Isabella labored to expell the Moors from Granada.

Some of the articles in this issue can, I think, help us attain a sensibly balanced perspective of our times. The Viking article (pages 6-8) shows what a remarkable achievement the Viking mission has been. But the Viking mission grew out of the ashes of a more ambitious Mars program in the late 1960s, and almost was cancelled in the early 1970s. (Instead, it slipped two years.) To get a feel for the time involved in some scientific research, consider that for more than 50 years, hundreds of astronomers have been classifying stars (see pages 10-12). Their often tedious work is essential for filling out our still sketchy understanding of the evolution of stars.

So let us keep history in mind as we read about space industrialization (pages 14-15). Commercial use of space will evolve on a time scale that is short in terms of human history, but longer than some would wish, requiring our patience. On the other hand, allow me to urge some of you to show a bit of *im*patience and make things happen. Waiting patiently for life to pass by isn't very exciting.

## SECOND NOTICE!!!
## REGISTRATION RENEWAL for complimentary mailing of *Air & Space*, a mini-magazine for educators

*Air & Space* Magazine will continue to be available at no charge to educators who are currently registered. If you did *not* return the *blue* renewal card bound into the Fall 1980 issue, and you wish to continue receiving *Air & Space* Magazine, please print the *code number* from your mailing label in the boxes below. Your card must be received at NASM by January 10, 1980 to continue your registration.

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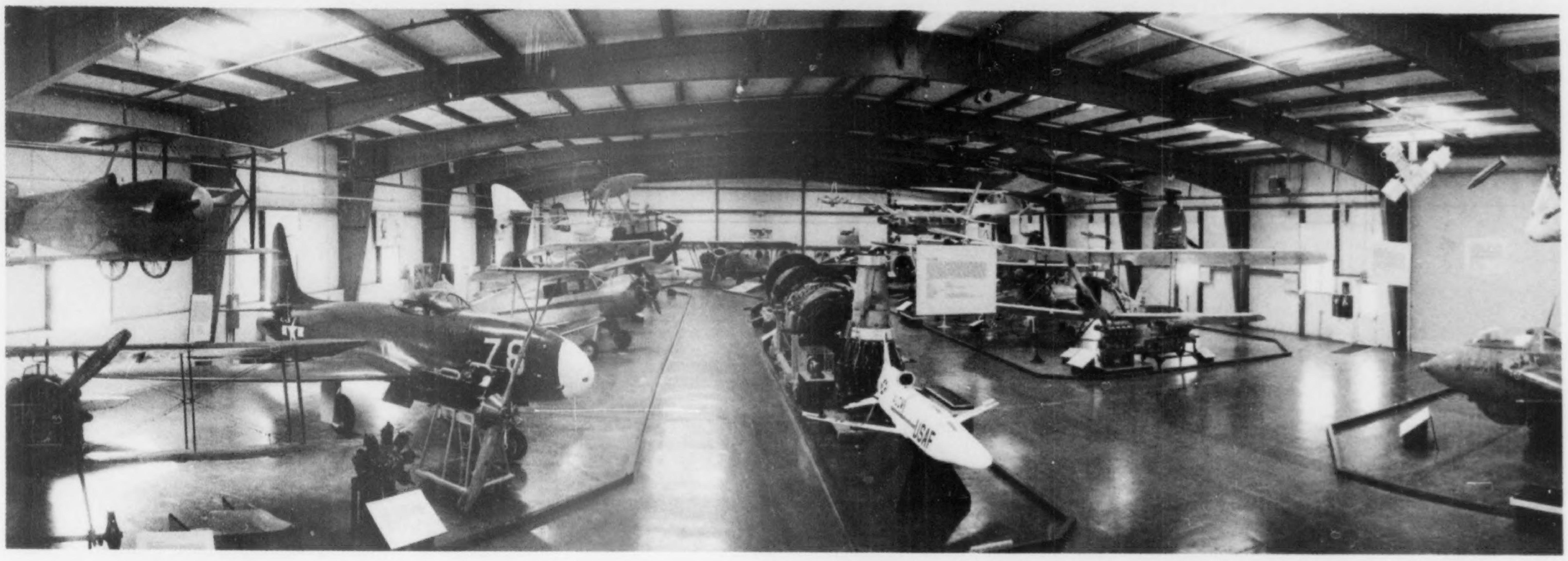


*Building 24 (of 25) at the National Air and Space Museum's Paul E. Garber Preservation, Restoration, and Storage Facility in Suitland, Maryland shelters dozens of historically significant aircraft, spacecraft, and flight-related objects. Visitors may see these and more on scheduled tours.*

# NASM'S "OTHER" MUSEUM

**by Robert C. Mikesh**
**Curator of Aircraft**
**Department of Aeronautics, NASM**

Somewhere in Maryland, the story is sometimes told, are a number of old hangars overflowing with nearly forgotten old airplanes. The runways at the airfield disappeared long ago, leaving the airplanes stranded.

The location of these "old hangars," which actually are steel warehouse buildings, is the National Air and Space Museum's Paul E. Garber Preservation, Restoration, and Storage Facility at Silver Hill, Maryland, on the southeast edge of Washington, D.C. This facility serves as a gathering and holding point for the Museum's vast collection of aircraft, spacecraft, aero engines, and other flight-related objects. It is here also that these artifacts, including those "old airplanes," are restored to like-new condition, preserving the technology of our aviation heritage for many years to come.

On display in the National Air and Space Museum in downtown Washington are some 68 of the 272 aircraft in the Museum's collection. Except for the 50 or so on loan to other museums, the remainder are kept at the Garber Facility.

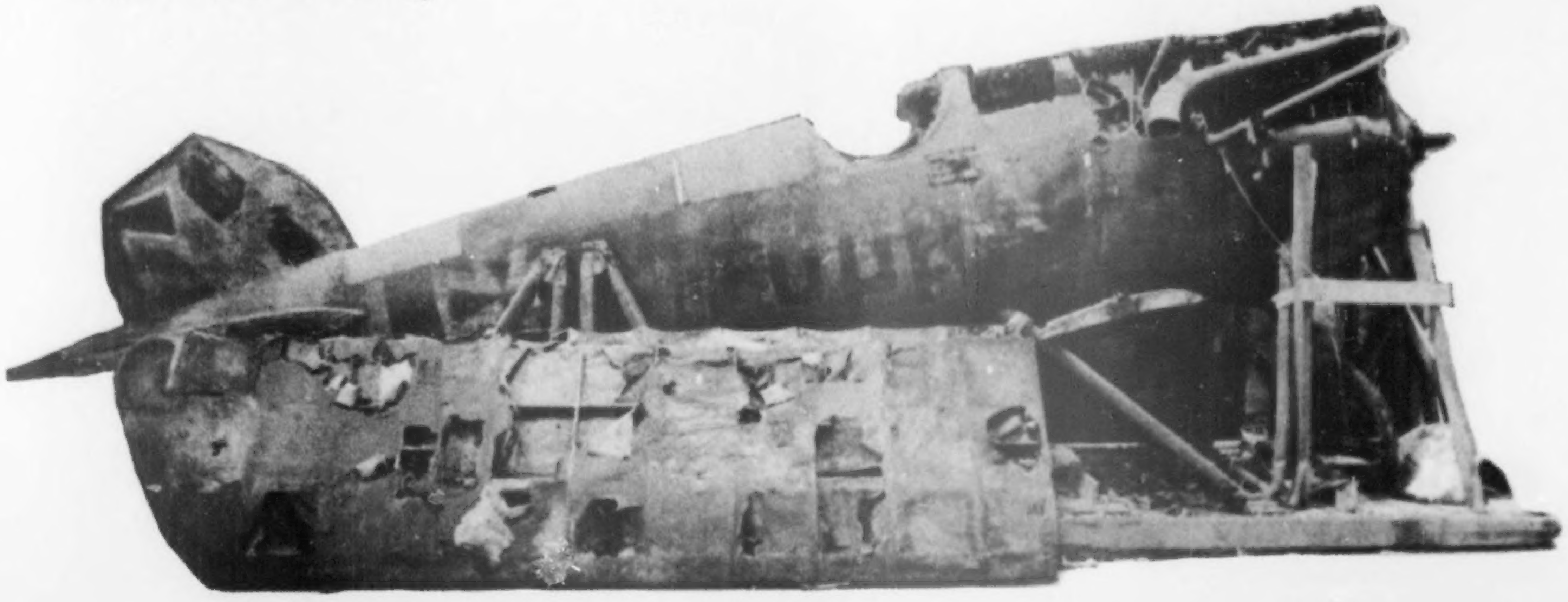
For many years, this airplane collection was a disarray of huge boxes containing major components of disassembled airplanes ranging from frail, turn-of-the-century craft to heavy military aircraft of the 1950s. Warehouse buildings sheltered the vast collection of aircraft engines and some of the more fragile airplanes. When our nation's space program grew, the Museum's warehouses began to fill with historic artifacts of space science and exploration.

As the Museum obtained more resources and erected larger warehouses, this growing collection of airplane parts was turned into a "no-frills" museum. The Garber Facility does not have the effective lighting or audiovisual systems found at the downtown Museum. Instead, the bare walls of five large buildings protect tightly-spaced rows of assembled airplanes that may be inspected by researchers and aviation historians. Virtually every shape, size, color, and vintage of aircraft is represented here.

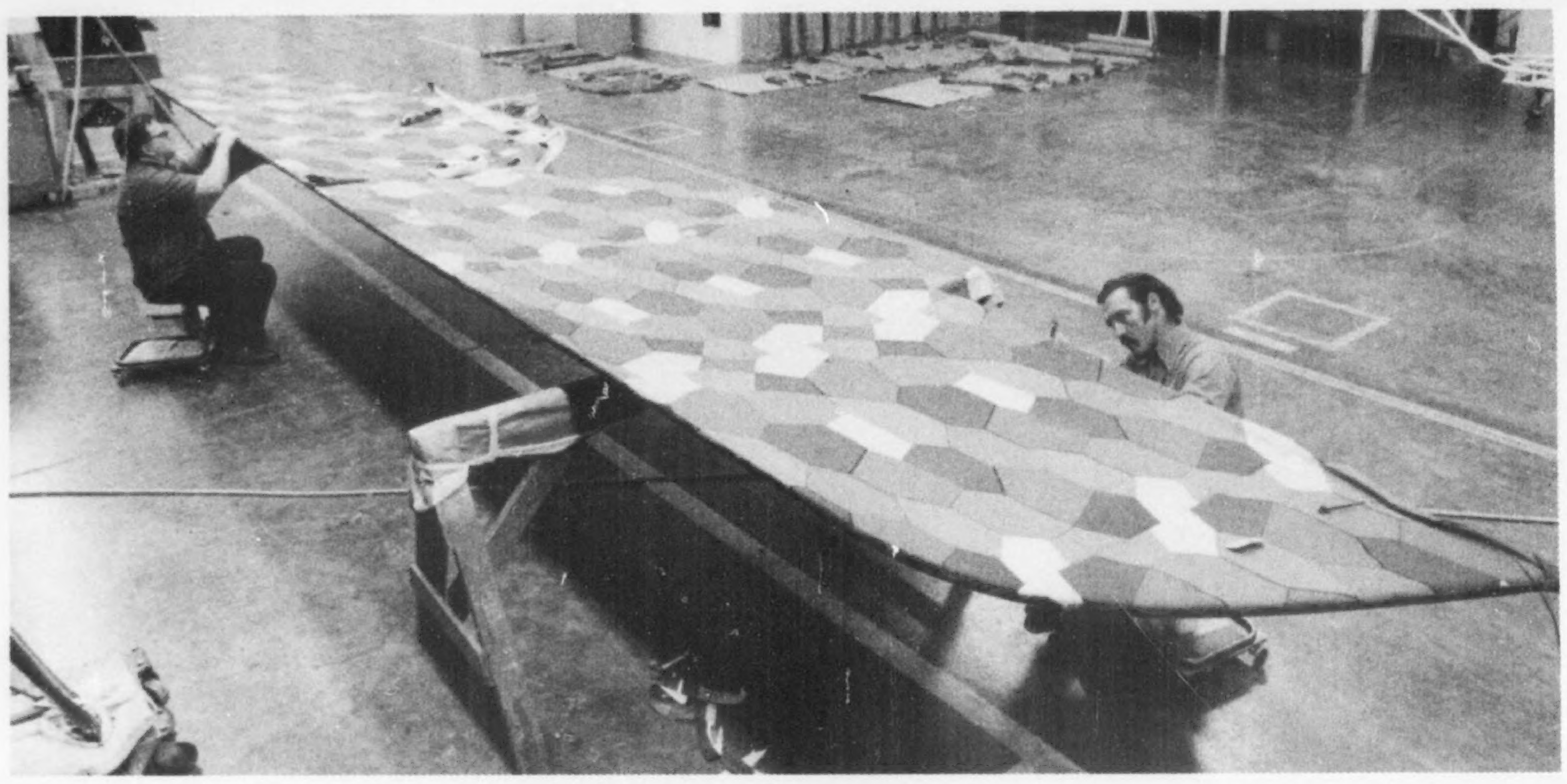
The public may view this study collection on an appointment basis. Well-informed volunteer guides lead small groups of visitors along the lines of airplanes on scheduled tours requiring advanced reservations (see box, page 4). The guides identify each airplane or spaceflight object on the tour and give a brief account of its history.

The most fascinating stop along the tour is Building 10, the workshop in which the Garber Facility staff each year restores four aircraft and more than 20

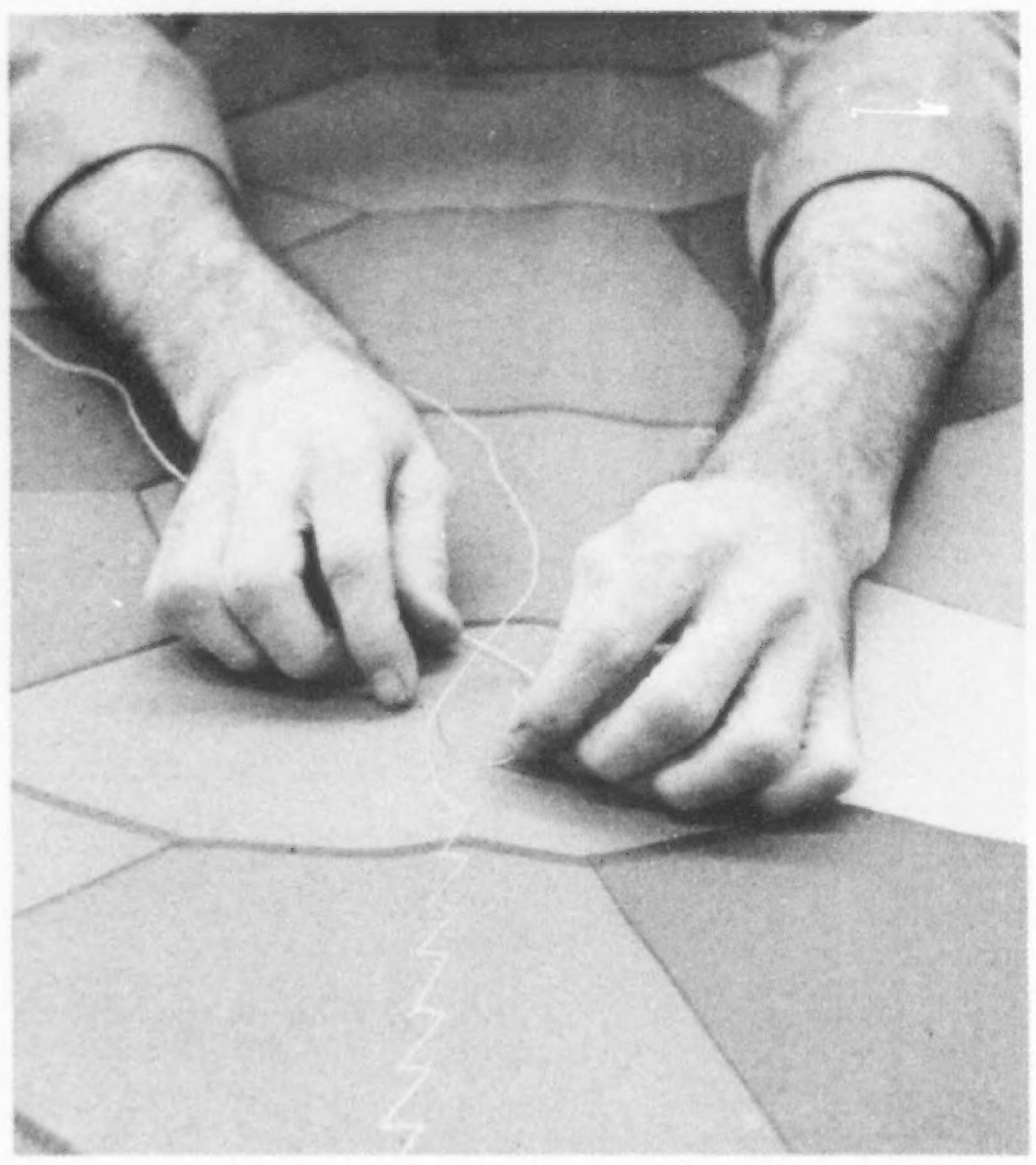
*Acquired in bad condition, NASM's Albatros D. Va World War I German fighter (see front cover) was stored until January, 1977 when restoration began. Many more aircraft in varying states of disrepair await restoration at NASM's Garber Facility.*



Related Flight series filmstrip: *The Challenge of Restoration* (see back cover).

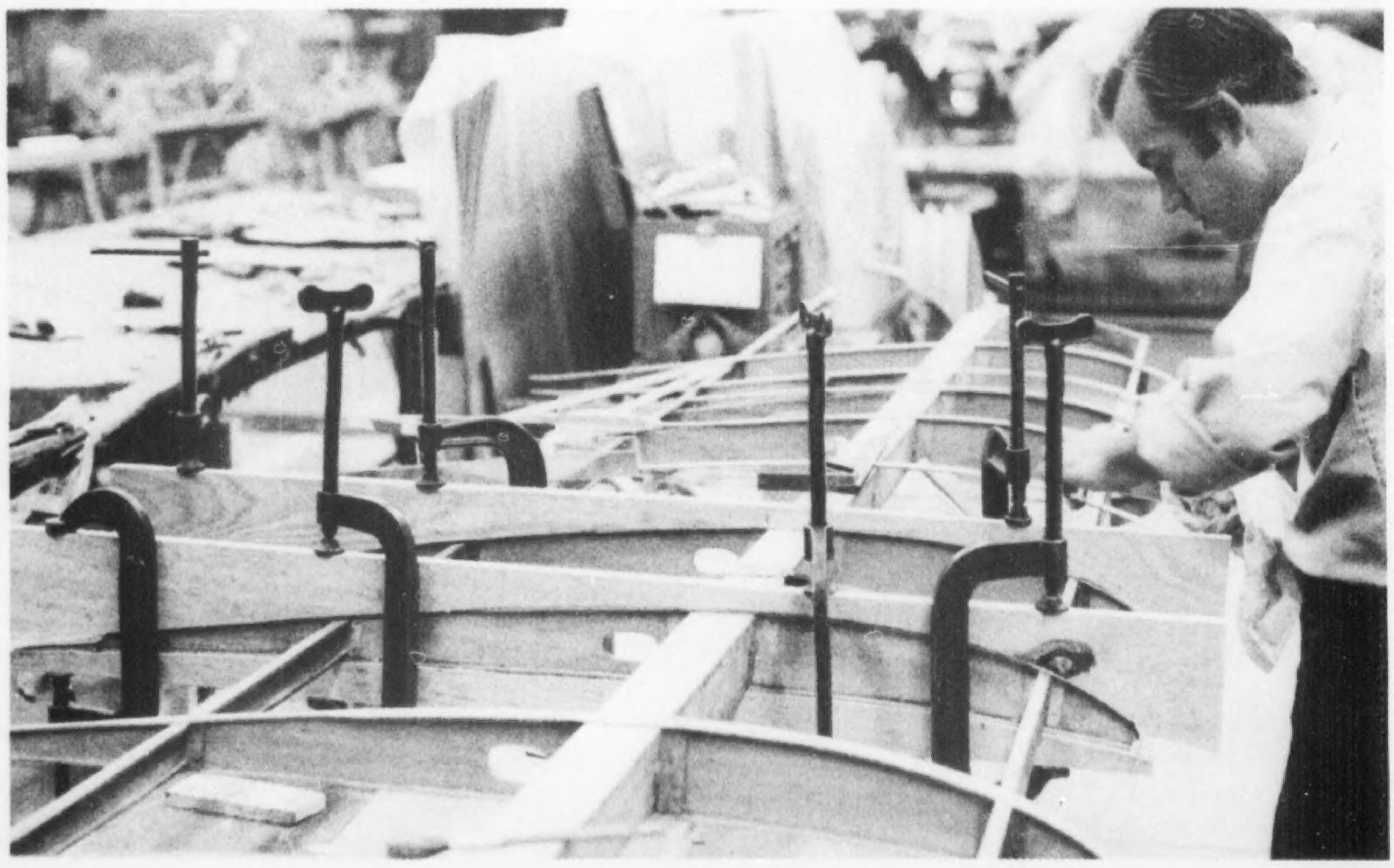


*John Cusack (left) and Walter Roderick (right) join the top and bottom cotton covering on the Albatros' upper wing with the prescribed baseball-type stitch. Restoration at the Garber Facility requires the diverse skills of a team of technicians experienced with a broad range of materials and methods, from engine overhaul and welding to upholstery and treatment of metal corrosion.*



*Painstaking accuracy—often hidden—is the trademark of Garber Facility craftsmen. Left: Stitching camouflage fabric to a wing rib. Right: Richard Horigan paints stripes over serial number, as did Germans.*

*Garry Cline reassembles linden (basswood) ribs around the Albatros' lower left wing spar. Plywood templates clamped over the ribs help retain accurate airfoil contours while gluing rib caps to ribs. Cline and co-workers devoted 2226 man-hours just to restoration of the Albatros' wings.*



aviation artifacts to their original condition with painstaking accuracy. Some of the aircraft need only to be taken apart, cleaned, and put back together. Most, however, have deteriorated through time, or were modified during years of use. Thus restoring them to their original condition, or to the most significant configuration of that aircraft type, becomes a difficult and time-consuming labor of love.

Sixteen highly skilled technicians make up the restoration staff. To best utilize their varied skills, these craftsmen usually work on two all-metal and two wood-and-fabric airplanes at any given time. Two museum technicians are assigned to each airplane. Other specialists, such as a machinist, sheet metal worker, welder, and metallurgist, help where needed.

The shop is equipped to restore or reproduce most aircraft parts, from upholstery to engine components. New parts are stamp-dated to distinguish them from originals. Making new parts often would be much easier than restoring the originals. However, making new parts is a last resort, for it is the responsibility of the National Air and Space Museum to *preserve* significant aviation and spaceflight technology.

In keeping with that responsibility, the Garber Facility does not just restore airplanes for specific exhibit needs, though once they are restored, these airplanes will last indefinitely and be available for whatever exhibit needs arise in the downtown Museum.

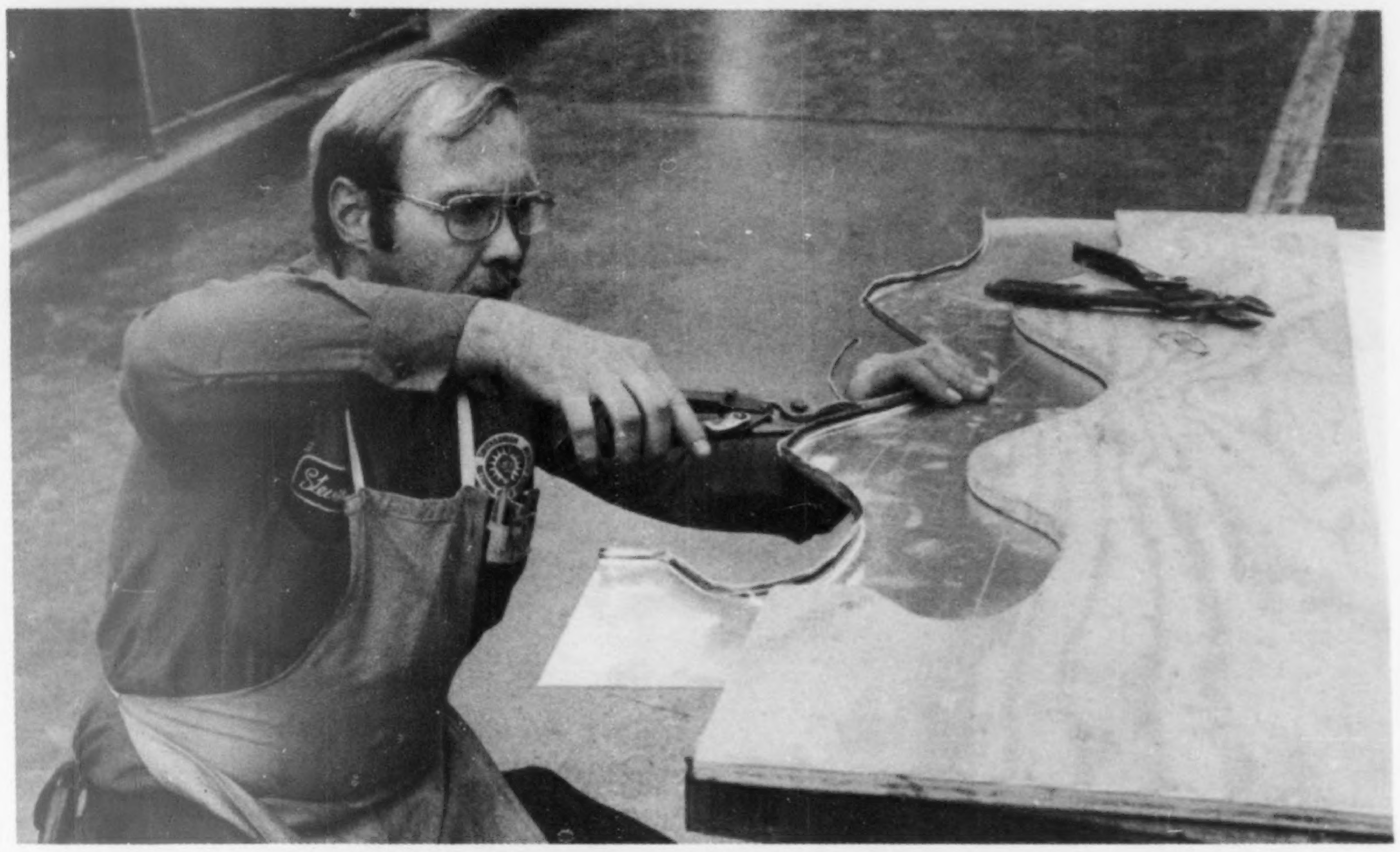
Before starting actual restoration of an airplane, Museum curators and the photographic staff take many photo-

### Free Tours

of the Paul E. Garber Facility are available Wednesdays and Fridays at 10 a.m., and Saturdays and Sundays at 10 a.m. and 1 p.m.

Reservations must be made at least two weeks in advance. For reservations or further information, call (202) 357-1400 between 9 a.m. and 4 p.m., Monday through Friday, or write: Tour Scheduler, Education Services Division, National Air and Space Museum, Washington, D.C. 20560.

Individuals or groups of up to 40 are accepted for the guided tours, which last approximately two hours. Special tours for handicapped visitors are available upon request. The warehouse-type exhibit areas are not heated or air-conditioned, so visitors should dress appropriately.



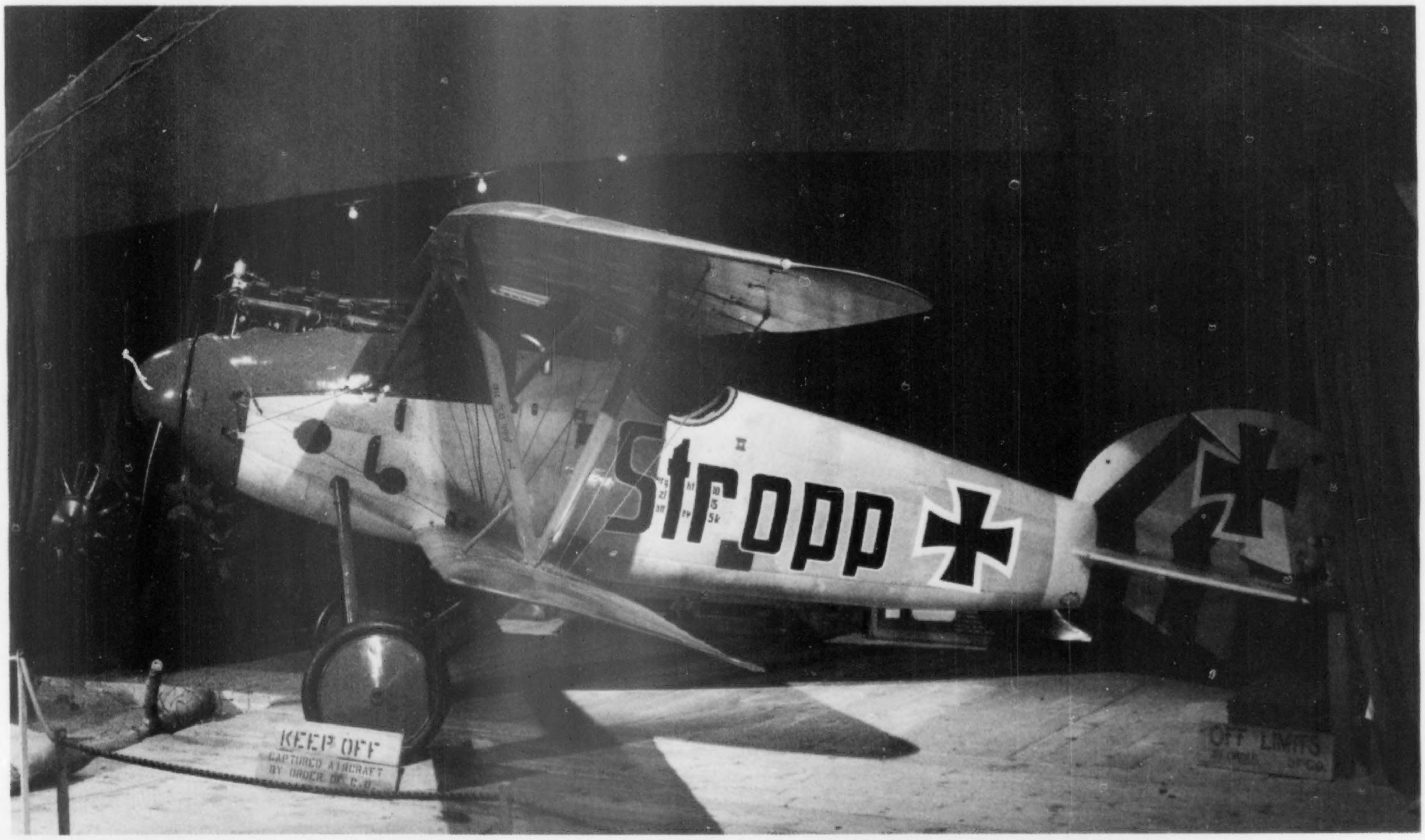
*Snipping carefully, sheet metal worker Bill Stevens shapes sheet aluminum to fit a plywood template cut from a heavy paper pattern. Stevens spent many hours with a blowtorch and pneumatic hammers crafting the smoothly contoured complex curves of the Albatros' new cowl.*

graphs of details on the airplane for later reference. Then the Garber Facility craftsmen disassemble the aircraft as completely as possible so that they can thoroughly clean its many parts. Chemical treatment of metal components to remove and arrest rust and corrosion is a very important part of the restoration process. Metal corrosion control often is as important in restoring wood-and-fabric aircraft as it is in all-metal aircraft. After repainting the parts with paints matched to the original colors, the restoration staff reassembles them. Restoring a single airplane requires 3000-7000 man-hours, depending on the aircraft's complexity and condition.

More than 90 percent of the restoration effort goes into the internal structure of the aircraft and is hidden from view after the project is complete. Visitors may admire only the authenticity of the restored aircraft's markings, but Museum personnel who were responsible for the restoration are satisfied that the aircraft is not deteriorating on the inside. They have every reason to be proud of their match of original construction techniques—sewing wing fabric with an outdated stitch, reapplying the same type of rivets, reshaping a damaged portion of the structure, or carefully recreating missing pieces.

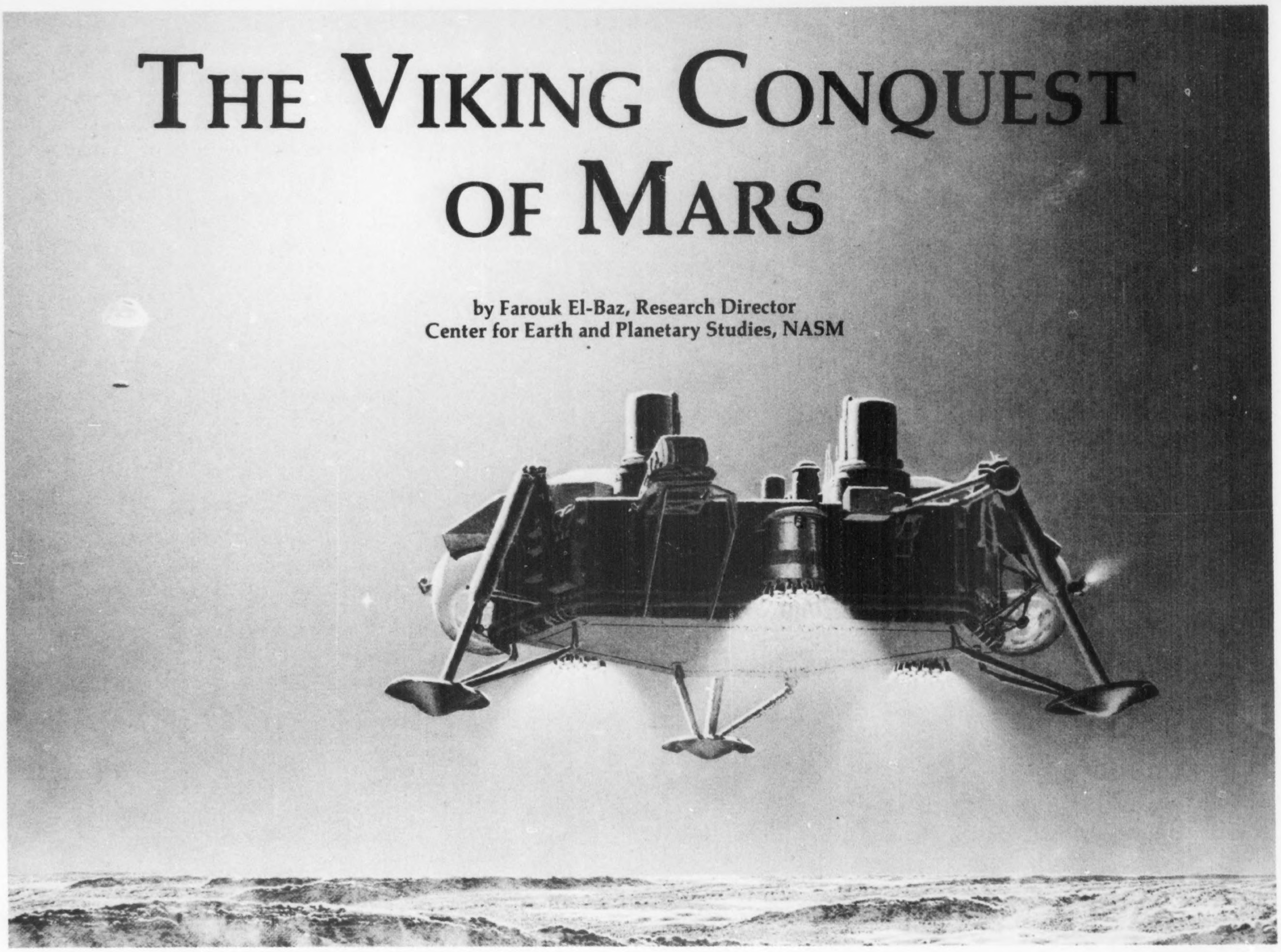
The Garber Facility formerly was called the Silver Hill Facility, from its location in suburban Maryland. On June 1, 1980, it was renamed to honor Dr. Paul E. Garber—now Historian Emeritus and Ramsey Fellow of the Museum—on his 60th anniversary of continuous service to the Smithsonian Institution. It is fitting that this Preservation, Restoration, and Storage Facility bears his name, for he located and initially developed this site when the National Aeronautical Collection had to be moved in a hurry from a temporary storage point near Chicago in 1951. Dr. Garber had the foresight to obtain significant airplanes long before that time, forming the nucleus of the largest collection of historic aircraft ever assembled by one museum.

*Restored to pristine splendor, the "captured" Albatros D. Va reposes at a recreated 1917 Allied front-line base in NASM's World War I gallery.*



# THE VIKING CONQUEST OF MARS

**by Farouk El-Baz, Research Director**
**Center for Earth and Planetary Studies, NASM**



*Slowed first by aerodynamic drag, then parachute, and finally by retro-rockets, Viking Lander 1 touched down on Chryse Planitia (Plains of Gold) on the planet Mars on July 20, 1976. Visible in the left background of this artist's conception of the landing are the Lander's aeroshell and parachute. Viking Lander 2 landed September 3, 1976 on Mars' Utopia Planitia. Together with the Orbiters from which they separated, the Viking Landers were the first spacecraft to undertake detailed, long-term scientific studies of conditions on the surface of Mars.*

The ancients associated the baleful glare of the red planet with hostility, and named it Mars, after the Roman god of war. When Asaph Hall discovered the two moons of Mars in 1877, he named them Deimos and Phobos, from the Greek words for terror and fear. Thus it was in keeping with a long-standing tradition that the spacecraft destined to conquer the "angry" planet were named Viking 1 and 2, after the intrepid Norse explorers.

The two Viking spacecraft were launched on August 20 and September 9, 1975, arriving at Mars in mid-1976. Each spacecraft consisted of an Orbiter and a Lander. The Orbiters performed nearly flawlessly, far outliving their design goal of three months in martian orbit. After running out of control gas, Orbiter 2 was shut off three years after launch, and Orbiter 1 continued to function until August 1980. The orbits of these now-silent spacecraft will slowly decay until the Orbiters finally crash onto the martian surface about 40 years from now. Viking Lander 1 continues to function, and is expected to continue to transmit weekly glimpses of the surface until its radioisotopic power source runs out at the end of 1994.

The Viking project, which cost one billion dollars, constitutes the most ambitious exploratory mission ever sent to another planet. These spacecraft transmitted to Earth more than 50,000 pictures of the rust-colored surface of Mars, studied its thin atmosphere, and looked for evidence of life in its soil.

The Viking mission revealed a planet to ponder. In some ways Mars appears Earth-like; in others it is similar to our Moon. In yet other ways it is unique.

**Life on Mars?**

In addition to photographing the surface, the Viking Landers analyzed the martian soil in search of evidence of life by using a biology instrument package that included three experiments:

A *carbon assimilation experiment* sought evidence of photosynthesis. Radioactive "labeled" carbon (bound to oxygen in the form of carbon dioxide gas molecules) was added to a scoop of martian soil in a chamber that simulated Mars' atmosphere. Instruments then determined whether or not any carbon had been assimilated, possibly by organic compounds in the soil.

A *labeled release experiment* sought evidence of the utilization of labeled organic matter. Metabolism of food by living organisms yields gases that indicate metabolic activity.

Finally, a *gas exchange experiment* incu-

Related Flight series filmstrips: *Great Spacecraft and their Accomplishments* (see back cover).

bated soil samples in dry, humid, and wet environments, both with and without "food" (amino acids, salts, and vitamins). Instruments monitored the samples for indications of metabolic processes.

Years after the first results of these experiments were obtained, the conclusions remain ambiguous, even after numerous simulations in laboratories on Earth. The carbon assimilation experiment, and particularly the labeled release experiment, yielded results reminiscent of those expected from a metabolizing system. However, the concurrent molecular analyses failed to reveal any organic compounds, even at the ratio of one part per billion. In addition, the gas exchange experiment results suggest the presence of a potent oxidizing agent. Such an agent might be capable of decomposing material with much the same result as biological "digestion." Thus the question of whether or not some form of life exists on Mars remains open.

### Mars' Atmosphere and Weather

The Viking Landers made one thing crystal clear: the martian atmosphere is vastly different from that of the Earth. Consider its components: nearly 96 percent carbon dioxide, 2.5 percent nitrogen, 1.5 percent argon-40, 0.1 percent oxygen, and traces of argon-36, krypton and xenon.

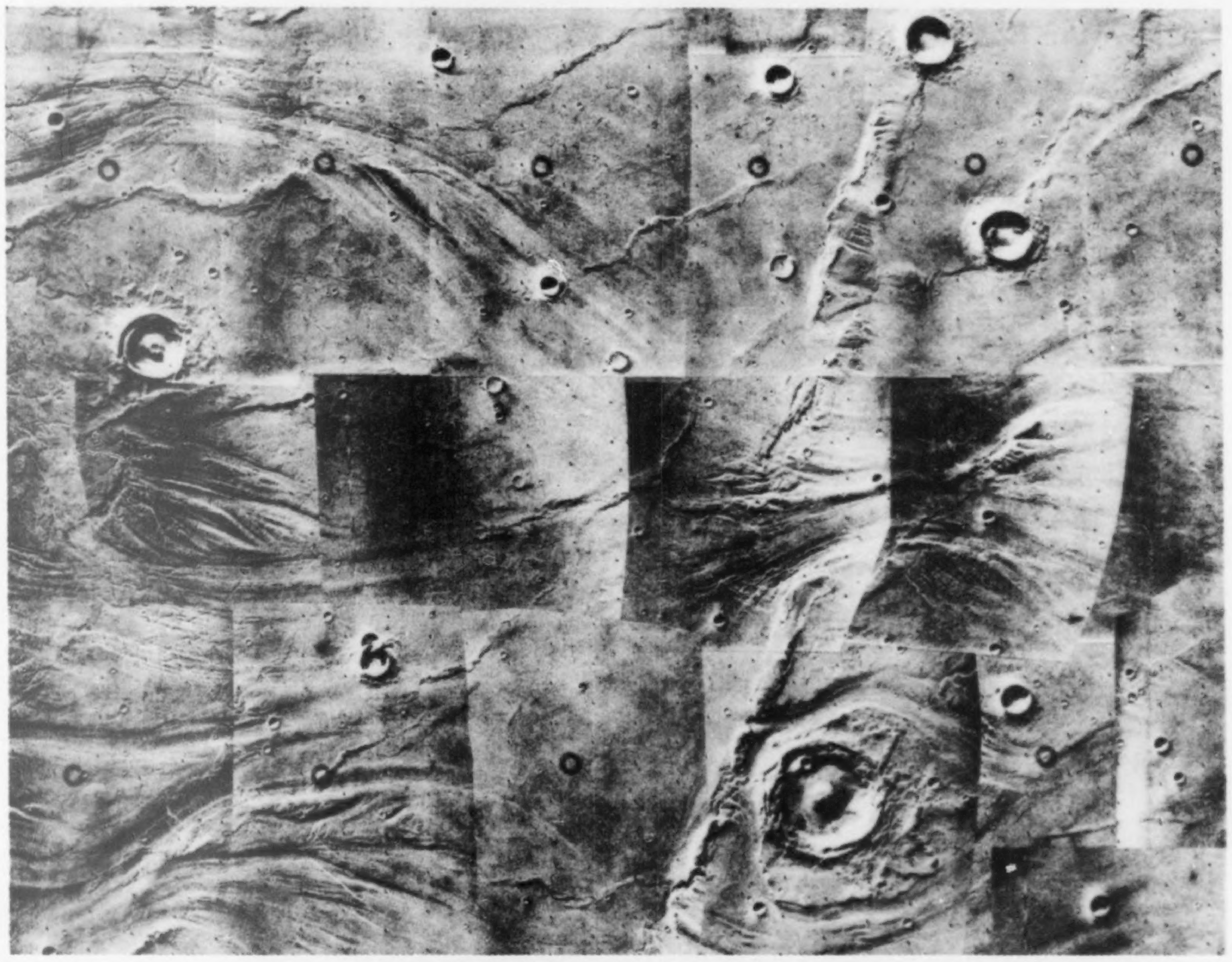
Martian atmospheric pressure varies from less than 7 to 10 millibars as carbon dioxide condenses on or sublimes from the polar caps. (Earth's sea-level atmospheric pressure averages 1012 millibars.) Peak temperatures during summer at the martian equator are about 20° C (68° F), plummeting to -140° C (-220° F) at night during the polar winter. Typical wind velocities on Mars are about 5 meters per second (11 miles per hour) with rare gusts reaching 50 meters per second (110 miles per hour). The planet's atmosphere is certainly characterized by complex meteorology.

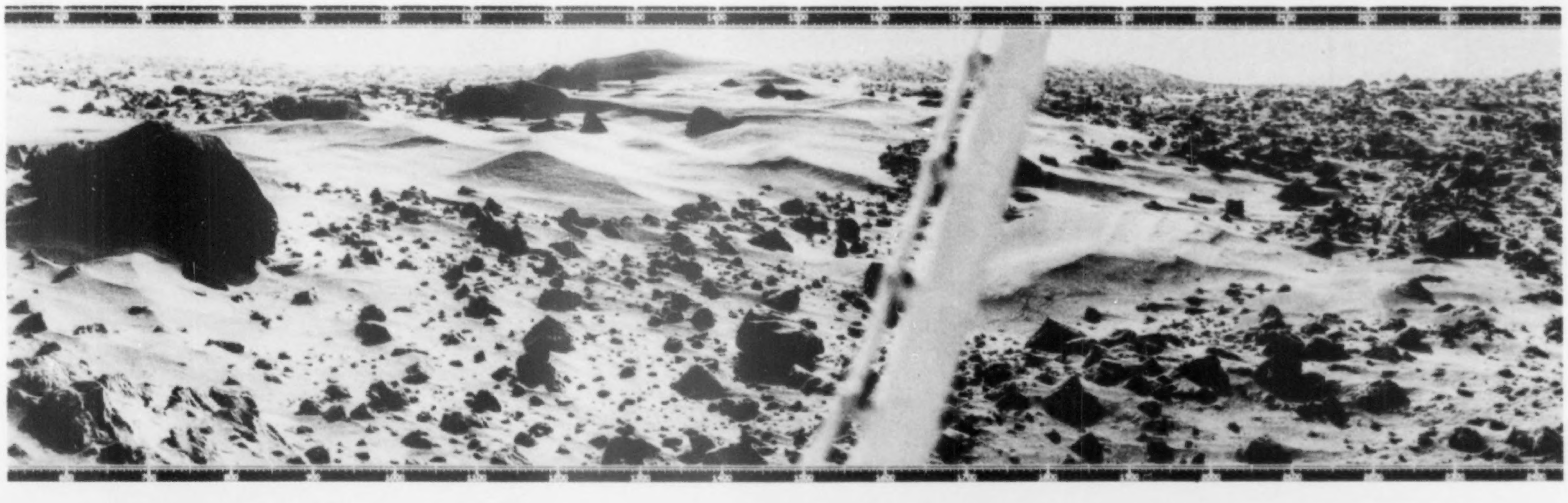
### Dust Storms and Dunes

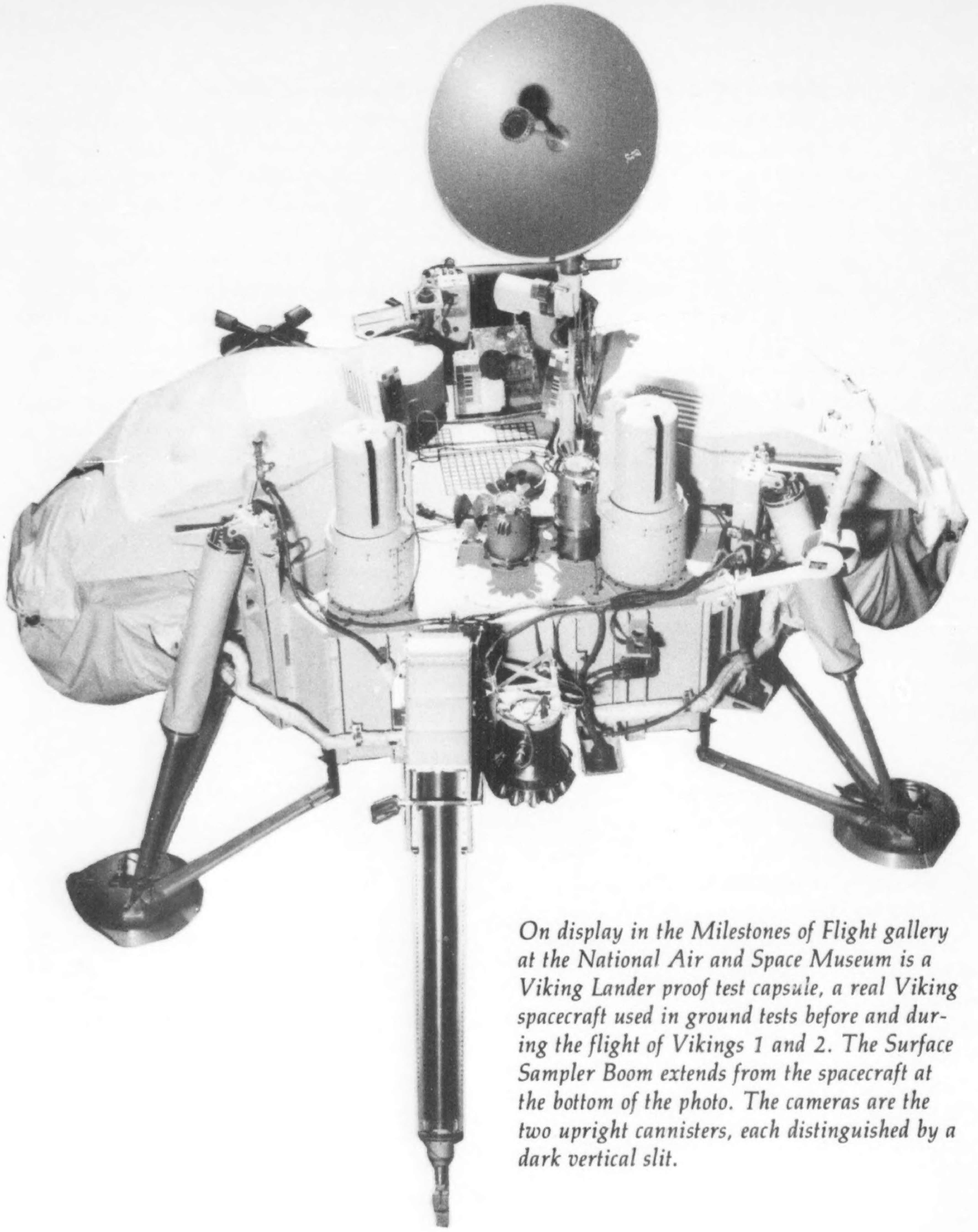
The Landers depicted few major changes on Mars' surface. Subtle changes resulted from the blowing of fine soil particles by the wind and formation of water condensates. The rates of change were disappointingly low; despite two global dust storms and several smaller ones during the Viking mission, the observable transport of material was confined to an extremely thin layer of bright dust.

The present-day low rates of erosion and material transport cannot be responsible for the many dune fields on Mars. Viking Orbiter images revealed an enormous field of crescent-shaped sand dunes around the north polar cap. This field is much larger than any of the terrestrial sand seas. On Earth, this type of crescent-shaped dune occurs where there is a reasonably large supply of sand and strong, highly directional winds. By analogy, the existence of such dunes on Mars supports prevalence of strong,

*Studying Mars from far and near vantage points respectively, the Viking Orbiters and Landers together gathered much more information about the martian surface than either could have alone. Right: A mosaic of 15 photographs of Mars taken by Viking Orbiter 1 from a distance of 1680 kilometers (1040 miles) covers an area of about 250 by 200 kilometers (155 by 120 miles). This broad view shows extensive lava flows broken by faults that formed ridges. Meteorite impact craters and the sinuous channels of ancient watercourses are clearly visible. In places, surface water may have ponded behind the ridges before cutting through to form "water gaps." Geologists believe similar processes shaped analogous terrain in the state of Washington. Below: This picture of the martian landscape taken by Viking Lander 1 shows a drift field with features similar to many seen in the deserts of the Earth. The sharply crested drifts and small deposits downwind of rocks indicate that the most recent winds capable of moving dust blew from left to right. The boom supporting Viking's miniature weather station is visible in the foreground.*







*On display in the Milestones of Flight gallery at the National Air and Space Museum is a Viking Lander proof test capsule, a real Viking spacecraft used in ground tests before and during the flight of Vikings 1 and 2. The Surface Sampler Boom extends from the spacecraft at the bottom of the photo. The cameras are the two upright cannisters, each distinguished by a dark vertical slit.*

sand-moving winds for long periods of time during Mars' geologic past.

### Lander Images: Pitted Rocks

Two cameras on each Lander took pictures of Mars' surface from a human-perspective height of about 1.3 meters (4.3 feet). Many of the images were taken in stereo pairs that allow three-dimensional viewing. Color renditions were made of some of the more than 4200 pictures of the rock-strewn landing sites. The rocks revealed in these images are believed to be volcanic basalts in a bed of fine-grained, reddish soil. The soil reddening is thought to be due to oxidation of iron from the basalt during weathering processes.

At the Viking Lander 2 site, the rocks exhibited pitted surfaces. These pits were interpreted as *vesicles*, spaces where gases were trapped in the fast-cooling basaltic lava. However, recent field research in the southwestern desert of Egypt, where pits in rocks are produced by wind erosion, suggests that what are called vesicles in the martian rocks may be wind-eroded pits.

### Orbiter Pictures: Ice, "Canals," and Volcanoes

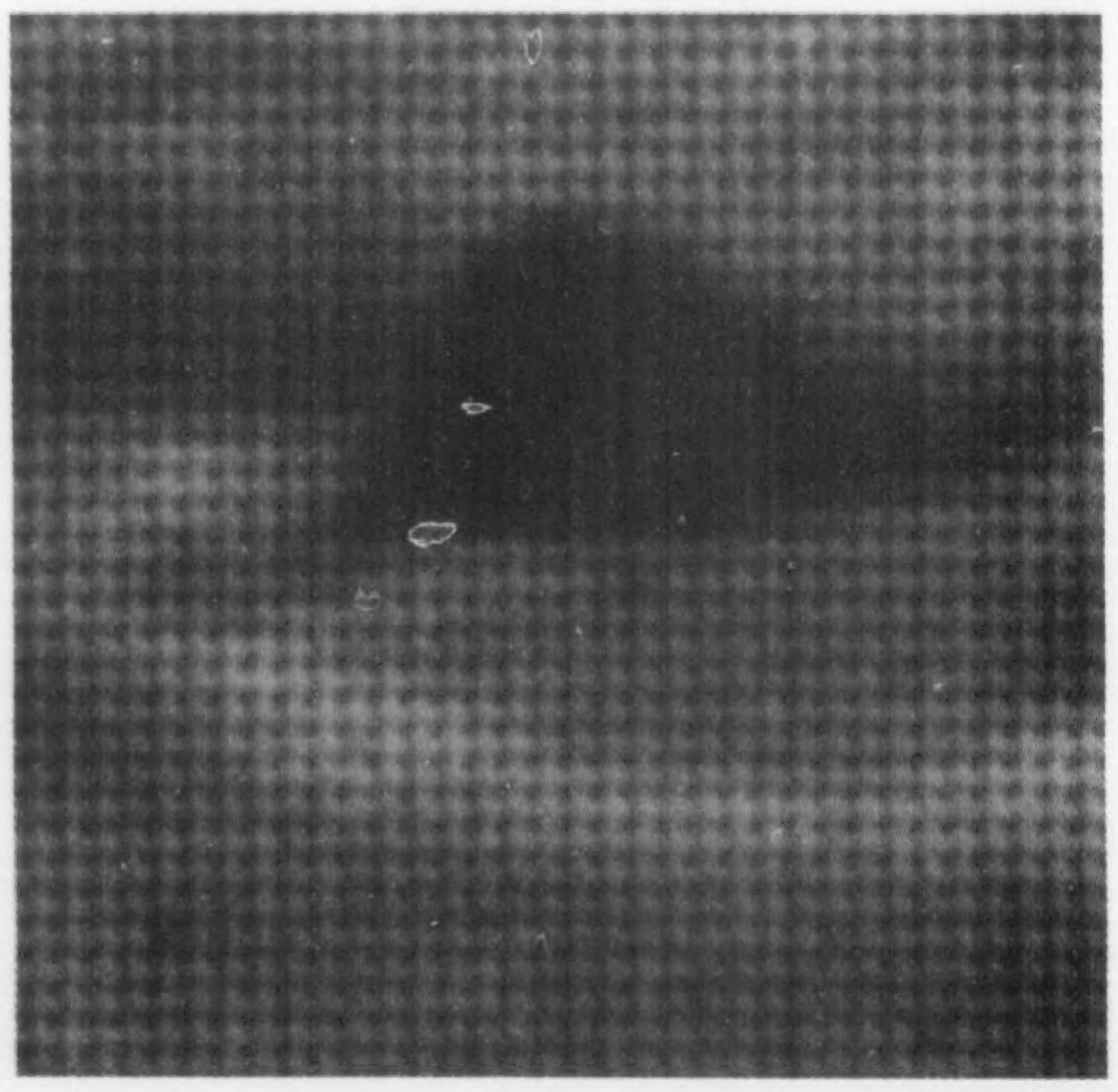
The Viking Orbiters did their share of solving old mysteries, as well as revealing new ones. Imaging instruments showed that Mars' northern polar cap consists mostly of water ice, while the southern cap is made of frozen carbon dioxide. Scientists have not come up with any easy explanations for this asymmetry.

The martian "canals" discovered by Schiaparelli in 1877 and described by many observers since then were not proven to be canals in the Viking Orbiter images. Yet long, curvilinear features do incise many parts of the martian surface. Some of these appear to have been formed by the action of flowing lava, collapse along fractures, and wind erosion; many, however, are nearly identical to channels formed by running surface water on Earth.

An example is what have been called "outflow channels" on Mars. These huge valleys range in width from 10 to 100 kilometers (6.2 to 62 miles); some of the channel complexes can be traced for more than 2000 kilometers (1240 miles). One terrestrial landscape reminiscent of these outflow features is the "Channeled Scabland" in the eastern part of the state of Washington. During the 1920s, geologists theorized that these deeply incised canyons were the product of an ancient, cataclysmic flood. Today, a new generation of geologists is measuring the Channeled Scabland features and comparing their morphology to similar features on Mars. The martian outflow channels are now also believed to be the result of catastrophic ancient floods that resulted from the sudden release of large quantities of water. The water on Mars is thought to have channeled the martian terrain and then disappeared, perhaps becoming permafrost under the martian soil.

The most imposing of the martian features are huge volcanoes that suggest sustained activity up to the present. Olympus Mons, the largest of the martian volcanoes, stands 27 kilometers (17 miles) high, has an apron of lava 500 kilometers (310 miles) across, and is more than four times larger than the largest Hawaiian volcanoes. The lava flows around the younger martian volcanoes display fresh-appearing cracks and fissures.

The success of the Viking project will be hard to top; the scientific harvest of this mission will serve generations of scientists to come. Yet its tantalizing discoveries make scientists dream of further explorations of the mysterious red planet.



*Left: Greatly magnified, Viking Lander pictures look like needlepoint. The pictures consist of a checkerboard of small, square, individual picture elements called* pixels. *Each Lander camera looks at its field of view as a corresponding checkerboard. To take a picture, it measures the light reflected from each tiny square. Computers then assign to each square one of 64 brightness levels, ranging from white through gray to black. Thus the reconstructed view of Mars looks, close up, like a needlepoint sampler made from 64 different shades of gray yarn.*

# Viking Student Activity

by Janet K. Wolfe
Unit Chief, Outreach Programs
Education Services Division, NASM

The Viking mission goal was to increase mankind's knowledge of the planet Mars by observing and measuring the martian atmosphere and surface. The Viking Landers were crammed with sophisticated instruments; however, these devices were not the only tools used in Viking experiments. Even the Landers' footpads were pressed into the service of science.

The footpads—thick, plate-like disks—were attached to the ends of the three legs on each Lander. The function of the footpads was to support the spacecraft upon landing on Mars. However, each landing offered scientists an opportunity to conduct a simple observational experiment with the footpads that can be simulated in the classroom. In a similar fashion, scientists learned about the mechanical properties of lunar surface materials in 1967 by studying pictures of the Surveyor spacecraft footpads and their imprints in the lunar soil.

Soon after landing, cameras began photographing the area near the Landers' footpads. The high-resolution images revealed martian surface materials ranging in size from fine-grained soils to rocks. Further investigations identified bulk densities of surface materials, particle size, and cohesion of drift material. The extent of the footpads' penetration into the martian surface, observations of the trenches dug by the spacecrafts' samplers, and rock nudging and pushing experiments provided even more information about Mars' surface.

### Activity

Students can simulate a part of the Viking experiment in the classroom. Have teams of students construct a series of surface beds from such materials as talcum powder, flour, sand, salt, dry cement, grain, pebbles (available in aquarium supply stores), and river rocks. For a footpad, students can use a metal pie pan secured to the end of a meter (yard) stick by tape, screws, or rubber bands. Be sure to weigh the pan before attaching it to the stick.

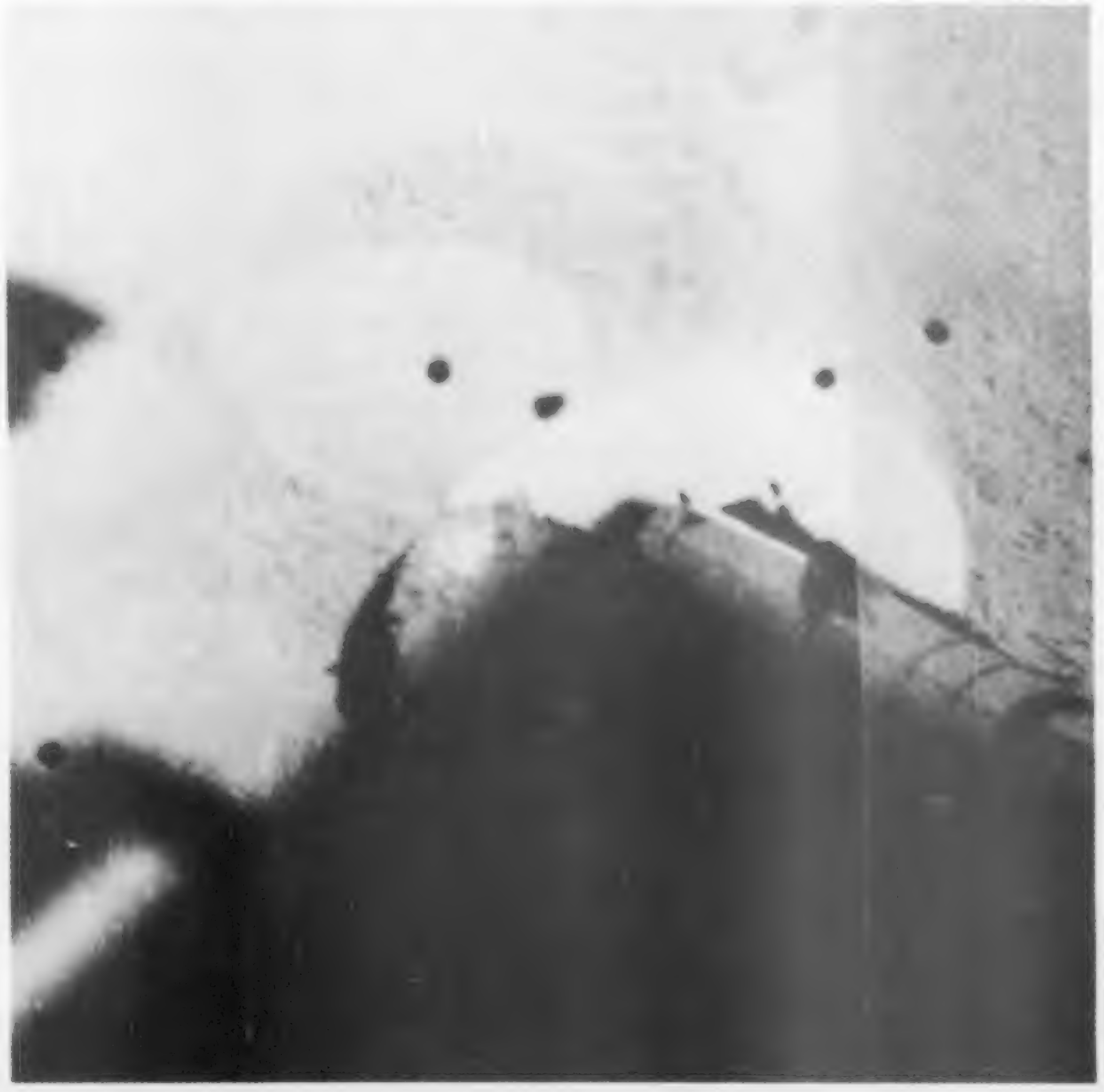
Students should mark a fulcrum near the other end of the stick and hold the stick between their fingers at this point. Have one student place the footpad 30 centimeters (1 foot) above the surface and allow the footpad to swing down for a "landing." Follow the same procedure for each surface bed.

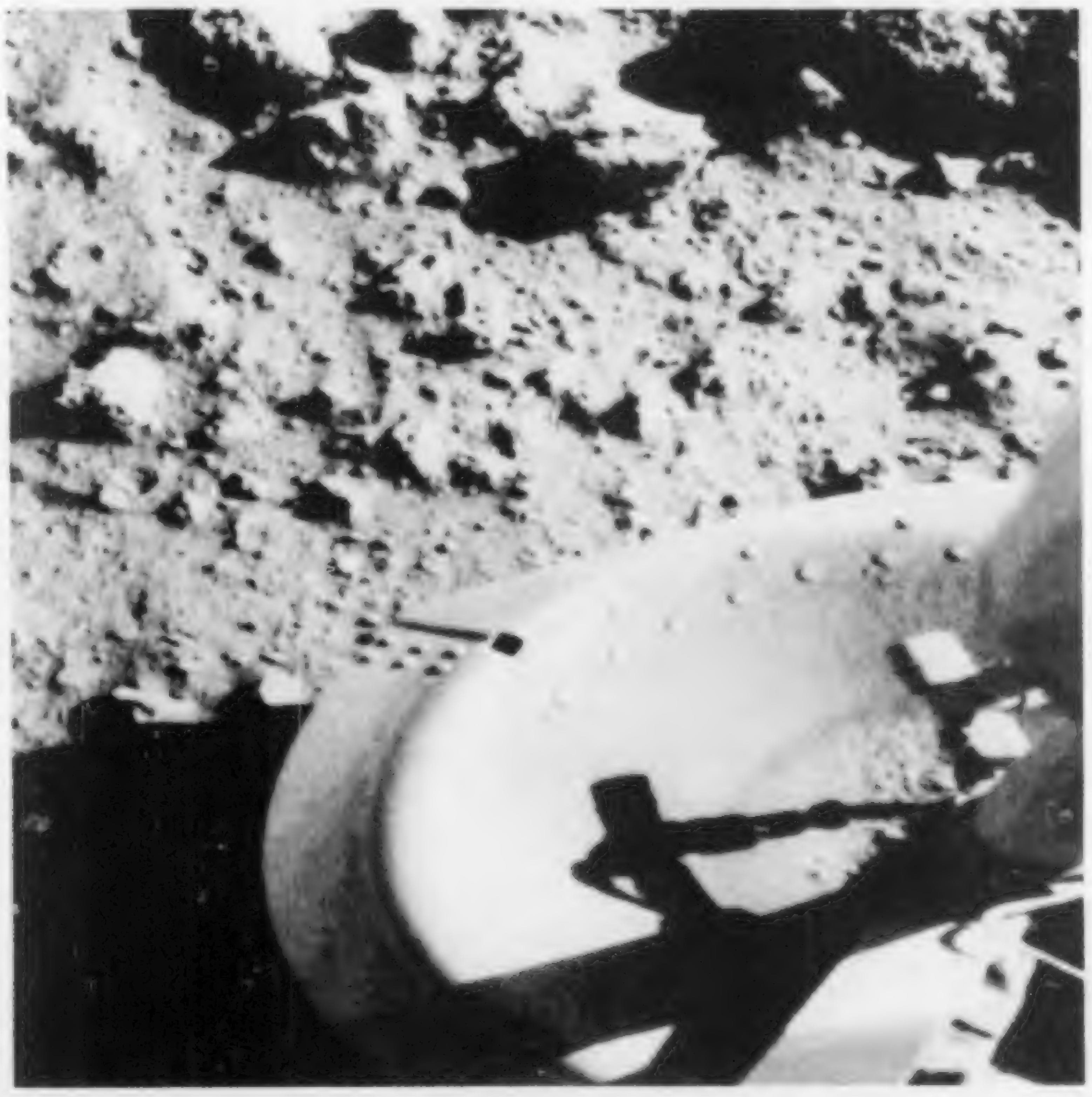
Ask students to record the similarities and differences that can be observed in the surfaces after impact by the footpad. For example, how far into the surface did the footpad penetrate? Did the footpad become completely covered by the material? What does this tell us about the bearing strength of the material? Did the surface material move? If so, how far? Did the surface material change position? If so, in what way?

### Options

Students may want to perform the experiment again by using a heavier or lighter footpad, or by slightly wetting the surface material before "landing." Ask students to make comparisons and draw conclusions based on their observations and measurements.

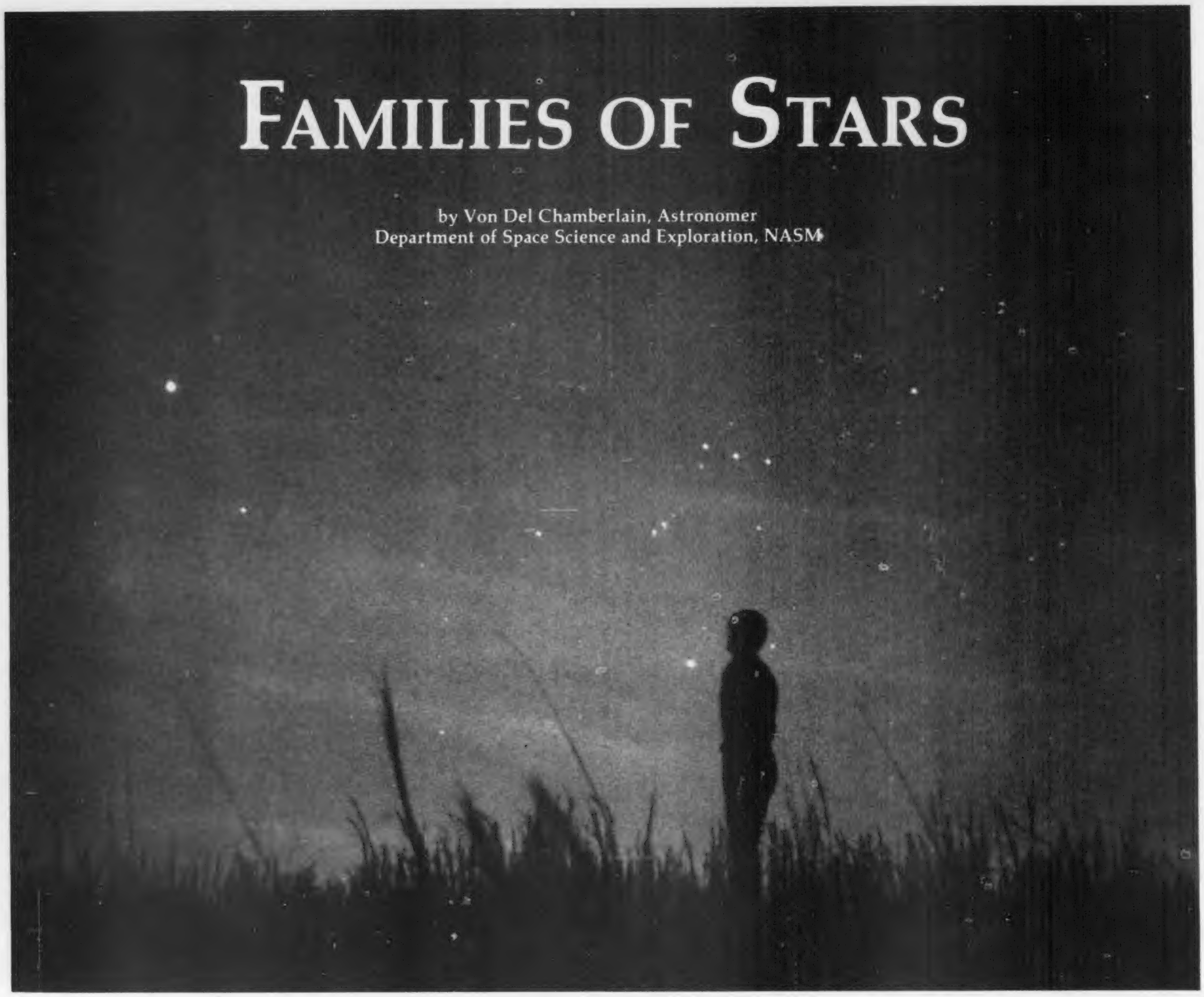
*Below left: Picture taken by Surveyor III on April 30, 1967, shows a double imprint of footpad just after Surveyor III bounced to a stop on the Moon. Viking scientists made predictions about martian surface materials based on the Surveyor footpad images from the Moon. Below right: First picture transmitted from Mars shows Viking Lander 1 footpad just after the spacecraft landed on July 20, 1976. Can you explain the differences between the two footpad images? Think about the effects of weight and terminal descent velocity of the spacecraft, gravity of the Moon versus Mars, and the presence or lack of an atmosphere.*





# FAMILIES OF STARS

by Von Del Chamberlain, Astronomer
Department of Space Science and Exploration, NASM



When we consider the small amount of light coming to us from any one star we see at night, it seems amazing that astronomers have been able to learn so much about the stars. For example, astronomers have been able to measure stellar distances. They have learned that the Sun is a common star. They have acquired a general understanding of how stars come into existence, how long they last, and what happens to them after they use up their internal energy sources. Astronomers also have gathered strong evidence that stars are the "factories" that made the chemical elements that are now rocks, plants, people, and everything else on Earth.

## Clues from Starlight

Astronomers since antiquity have yearned to understand the stars that they could not touch. Yet the stars reach down to us. The constant streams of light they send to our upturned eyes carry a great deal of information.

How have we gleaned detailed knowledge from such feeble light in the night? One very important part of the answer involves the ways astronomers have been able to classify the stars, or sort them into families.

A logical place to start to understand the stars is to compare them to one another. Imagine that you are out in the country on a clear, moonless night. What properties of stars can you observe with just your eyes? How do the stars appear to differ from one another?

Two things are immediately obvious. The stars differ in apparent brightness, and they seem to form patterns. One more quality becomes noticeable as you look more closely: the stars differ somewhat in color. A few appear redder than others; some look a bit yellowish; most appear white or blue-white.

What is the significance of these three observable features—brightness, pattern, and color?

## Brightness of Stars

Differences in apparent relative brightness would be very important if the stars were all the same distance from Earth. But we know that they are not. Some of the closest stars are not even visible to our unaided eyes, and some of the brightest are quite far away. We first would have to find a way to determine the distances of stars; then, knowing the distance of each star, we could use apparent brightness to calculate its actual brightness. If we could determine the actual brightness of each star, we could estab-

Related Flight series filmstrip: *Cosmic Awakening* (see back cover).

*Right: Color-luminosity diagram for the 100 brightest and the 90 nearest stars. Developed independently between 1911 and 1913 by the Danish astronomer Ejnar Hertzsprung and the American astronomer Henry Norris Russell, this chart is generally known as the Hertzsprung-Russell, or simply H-R, diagram. The luminosity scale shows the true brilliance of stars compared to the Sun. The temperature scale is in degrees Kelvin, which equals degrees Centigrade plus 273 degrees. Approximate color ranges are also indicated. The named stars are those that should be most familiar to readers who have used the Sky Maps regularly featured in* Air & Space.

lish true brightness families of stars. Astronomers have done that.

### Constellations vs. Clusters

What about stellar patterns? We think immediately of the constellations and the mythologies associated with them at various times and in various places throughout the world. But what significance do the patterns have?

Once again, the distance problem becomes important. An apparent pattern of stars has no physical meaning if some of the stars are very much farther away than others. If we can determine the relative distances of the stars, we can pick out star patterns that form real groups, or clusters. The Pleiades and the Hyades, both in the constellation Taurus (the Bull), are two examples of actual clusters of stars (see the January-February Sky Map, page 18). Some of the stars of the Big Dipper in Ursa Major (the Great Bear) are also part of a more widely separated, less densely populated cluster.

We have, then, two possible types of stellar families: true brightness families, and families of stars that are physically clustered together. In order to classify stars in either of these families we must be able to determine their relative distances from Earth. Now what about the color differences of stars? Can we form color families? Do these depend on distance also?

### Color and Temperature of Stars

The human eye is not a very good device for separating stars into color groups. To be more accurate in star color separation, astronomers use color filters and brightness measuring devices. They also split the light of each star into its color spectrum to find out which color of the star's spectrum is brightest. In these ways they establish color families of stars.

These color families are also temperature families. Color is a reliable indicator of the temperature of a star. Generally speaking, color families can be established without knowing the distances of stars.

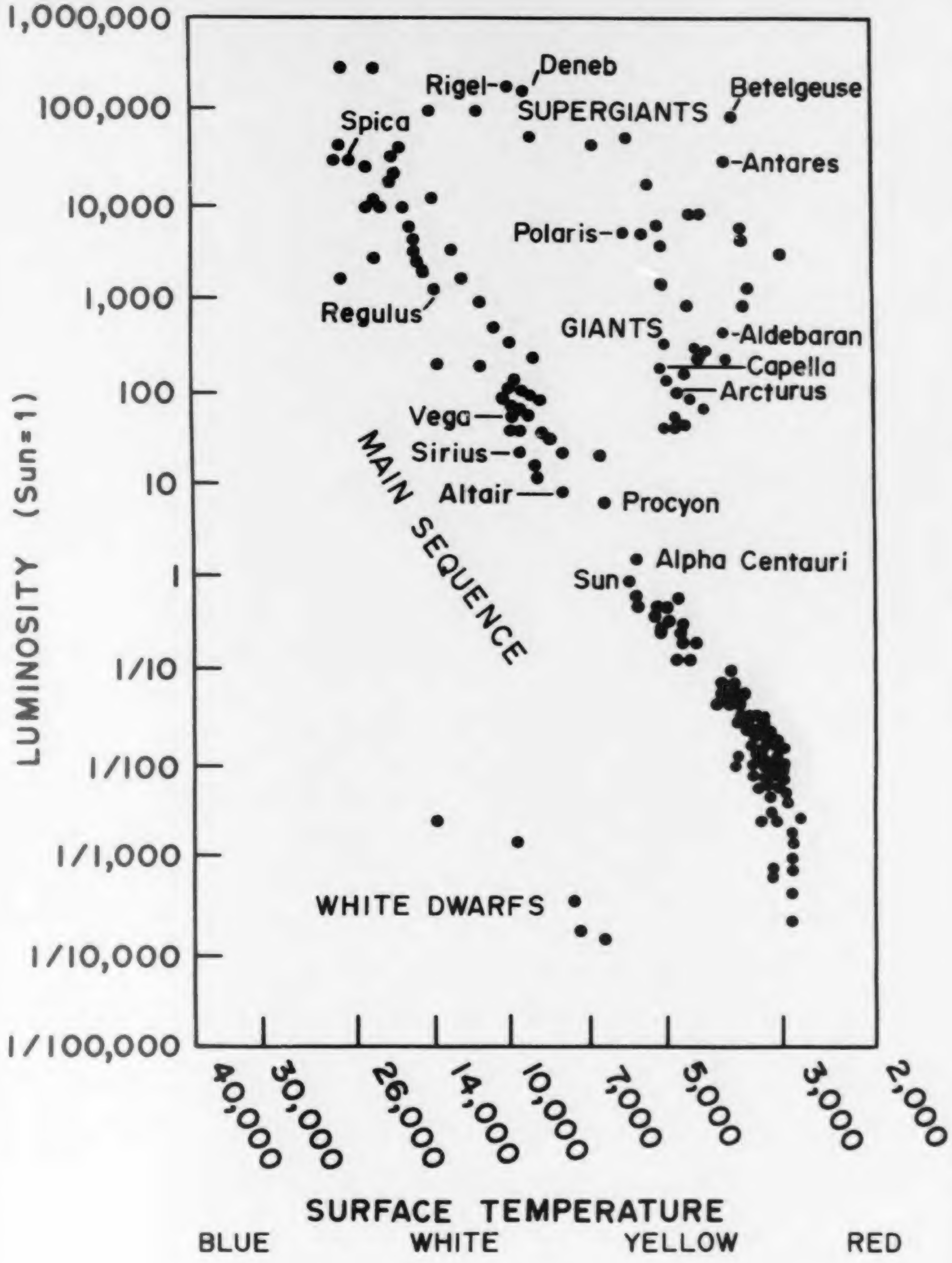


**Figure 1: Color vs. luminosity of selected stars**

### The Color-Luminosity Chart

Now we come to the most interesting part. These three types of families of stars—brightness families, clustered families, and color or temperature families—can be brought together in a very important way.

When we graph color or temperature against the true brightness of stars, we create the key to understanding the relative ages, masses, and sizes of stars. Indeed, color-luminosity charts of stars have made it possible to speculate on the entire evolutionary histories of stars. Such a graph of luminosity (brightness) and color is shown in Figure 1.

The first thing that seems important is the fact that the data points do not appear all over the chart—i.e., stars do not exist in all possible combinations of true brightness and color or temperature. Notice that most of the stars are distributed along the line labeled "main sequence," passing diagonally across the graph from blue-hot-brilliant stars to red-cool-dim stars. Fewer stars form groups across the top. The "supergiants" and "giants" are all brilliant stars ranging

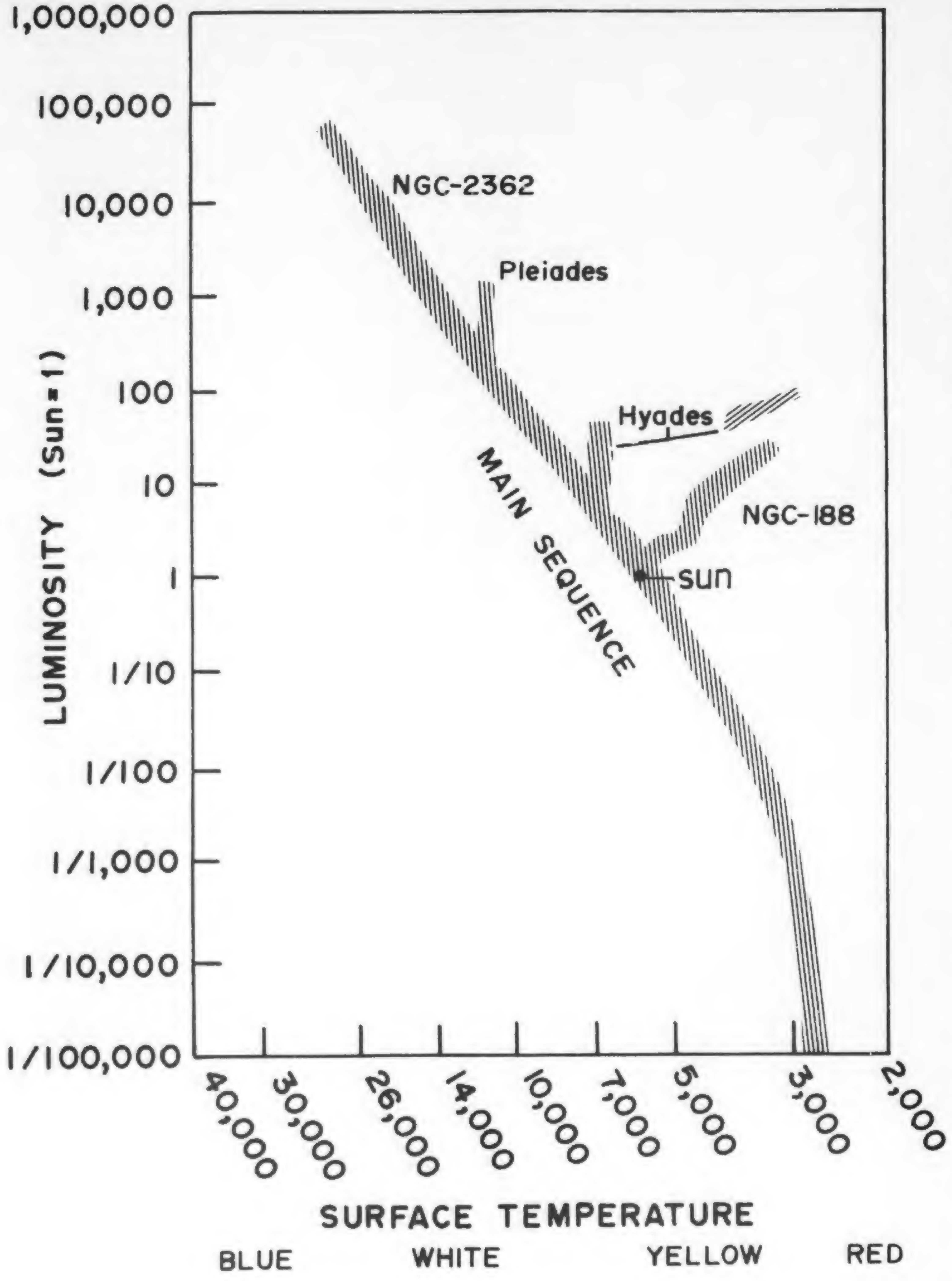


**Figure 2: Color vs. luminosity of several star clusters**

*Left: Superimposed color-luminosity diagrams for several clusters of stars. The points of departure of cluster stars from the main sequence indicate the ages of the clusters. Estimated ages for the clusters shown are: NGC 2362, about 1-2 million years; the Pleiades, about 100 million years; the Hyades, about 1 billion years; NGC 188, about 10 billion years. Both the Pleiades and the Hyades are visible to the unaided eye (see Sky Map, page 19).*

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from blue-hot to red-cool stars. There are still fewer white-hot, but very dim, stars ("white dwarfs").

If we consider only the main sequence stars, we find that those at the hot, brilliant end are also the most massive. Those at the cool, dim end are low-mass stars. Mass is the key to rate of evolution of stars. The high-mass stars are spendthrifts. They burn bright and hot and use up their vast stores of energy rapidly. The low-mass stars are misers, burning cooly and slowly and lasting on the main sequence for immense periods of time.

### Clusters and the Color-Luminosity Chart

Finally, our cluster families enter the picture. Because the stars in a given cluster are all at relatively the same distance from Earth, differences in their apparent brightness are real brightness differences. We can, therefore, plot a type of color-brightness diagram for clusters without knowing even the actual distances of the clusters. If we do this for many clusters on one diagram, superimposing their main sequences, we get the chart shown in Figure 2.

Notice how the lines representing the data for each cluster diverge from the basic main sequence. The point of divergence indicates the age of the cluster. The very massive, brilliant, hot stars of each cluster evolve rapidly and leave the main sequence to become red supergiant stars and, eventually, black holes. Lower mass stars evolve more slowly, so that the older the cluster, the farther down the main sequence we find the stars departing from the main sequence. The oldest clusters known, such as NGC 188 (see Figure 2), consist entirely of yellow-to-red main sequence stars and a few stars that have evolved into giants. The very massive stars are all gone, having completed their evolution as bright luminous bodies. The youngest clusters, such as NGC 2362, consist of stars all along the main sequence. Very few of their stars have evolved away from the main sequence, since the cluster has not existed long enough for even its most massive stars to do so.

We could say much more about the relationships between brightness, clustered, and color families. Much information can come out of what seems at first to be a small number of observable properties of the universe. The basic clues are easy to see. They have always been there in the night waiting for individuals to ask the right questions leading to the right measurements. Any of us can ask questions not yet answered; if we want the answers badly enough, we usually can learn how to find them. The first steps are simply to look and to ask.

## *Readings*

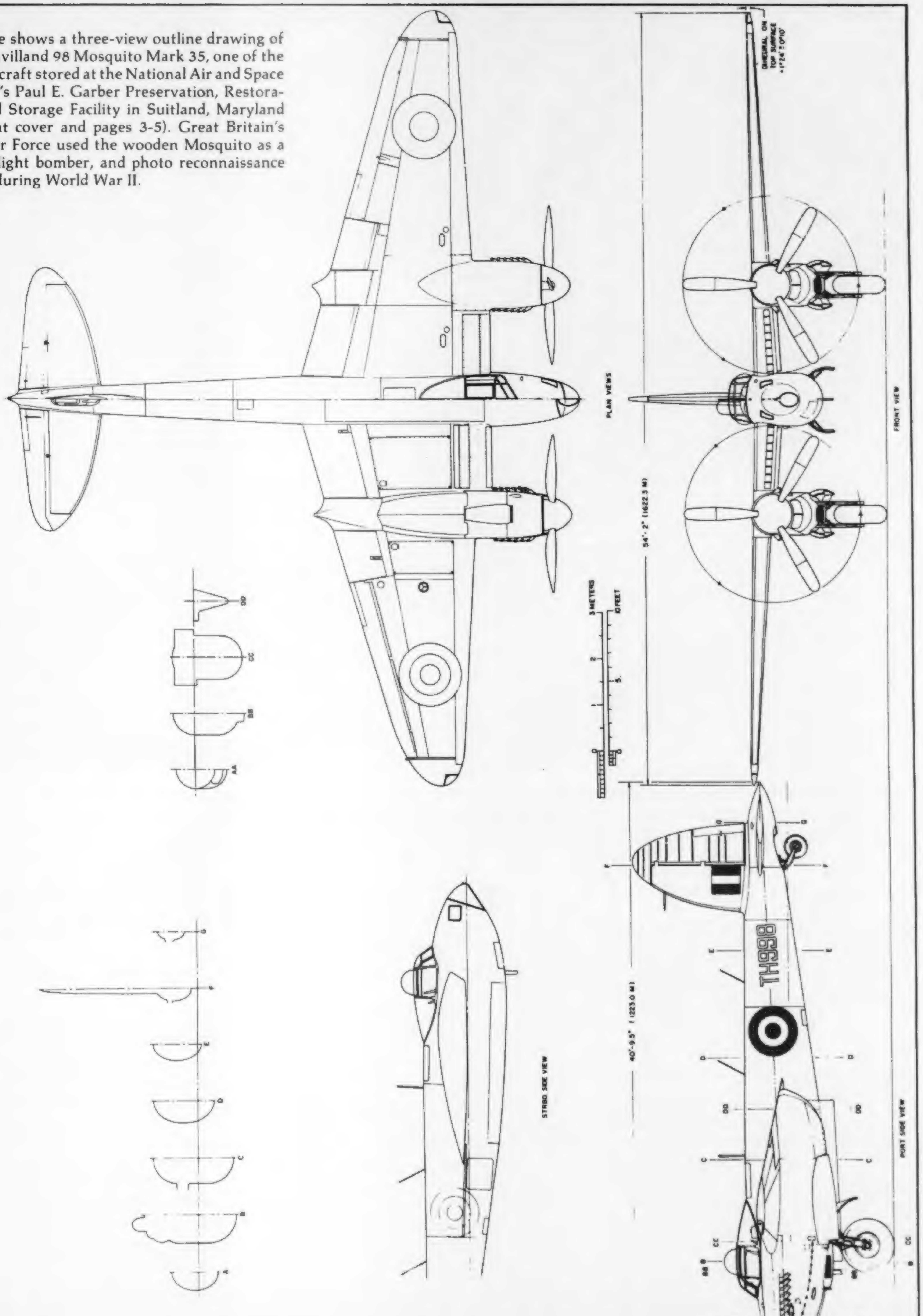
*The Amazing Universe*, Herbert Friedman. Washington, D.C.: National Geographic Society, 1975.

*Astronomy: A Self-Teaching Guide*, Dinah L. Moché. New York: John Wiley & Sons, 1978. Chapters 3 and 4.

*Astronomy: Fundamentals and Frontiers*, Robert Jastrow and Malcolm H. Thompson. New York: John Wiley & Sons, 1977. Chapters 4, 5, and 7.

*Astronomy: The Cosmic Journey*, William K. Hartman. Belmont, California: Wadsworth Publishing Company, 1978. Chapters 13-16.

This page shows a three-view outline drawing of the deHavilland 98 Mosquito Mark 35, one of the many aircraft stored at the National Air and Space Museum's Paul E. Garber Preservation, Restoration, and Storage Facility in Suitland, Maryland (see front cover and pages 3-5). Great Britain's Royal Air Force used the wooden Mosquito as a fighter, light bomber, and photo reconnaissance aircraft during World War II.


DIHEDRAL ON TOP SURFACE +1°24' ± 0°10'
PLAN VIEWS
FRONT VIEW
54'- 2" (1622.5 M)
3 METERS
10 FEET
TH998
40'-9.5" (1223.0 M)
STRBD SIDE VIEW
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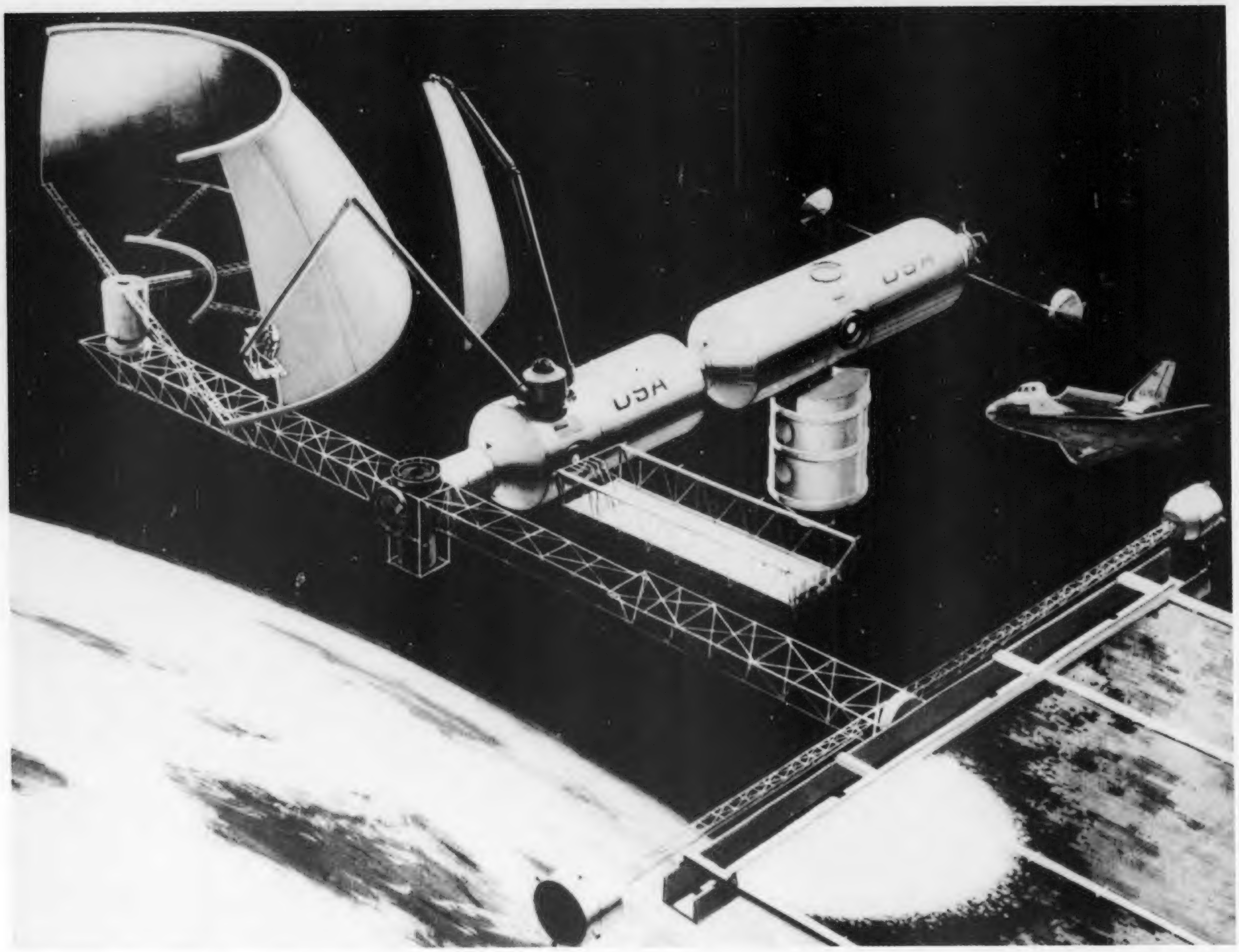


*Above: An artist's concept depicts a possible scene of future space industrialization, in which a permanent construction base orbits the Earth. Workers using "cherry picker" booms attached to a central module, powered by electricity produced in a huge solar panel array (right), construct a radiometer antenna (left) for remote sensing of terrestrial environments. The Space Shuttle, a key element in development of space industrialization, waits nearby.*

# SPACE INDUSTRIALIZATION

**by Kerry M. Joëls**
**Chief, Education Services Division, NASM**

Mankind's first view of the entire Earth, furnished by the Apollo 8 astronauts in late 1968, helped to promote a far-reaching public awareness of the finiteness of our planet and the fragility and interdependence of the components of its biosphere. One of the widely accepted theories that emerged at that time was the "limits to growth" hypothesis set forth by a group of scholars called the Club of Rome. This "limits to growth" theory saw the Earth as a closed system, with growing demands placed on its limited resources by an increasing human population. The Club of Rome's report started a widespread movement. Public belief that the world is running out of energy resources, raw materials, usable land, and options was reinforced by the 1973 oil embargo.

### Space Shuttle: Freighthauler for Space Industrialization

During this period, the United States made a commitment to build a reusable Space Shuttle, or Space Transportation System, creating a whole new capability for space exploration (see back issues of *Air & Space*). There was a concurrent rise in public interest in space activities and exploration, evidenced by the popularity of the *Star Trek* television series and the *Star Wars* movies. Futuristic ideas like space colonization and interplanetary travel excited the public imagination. Being the first reusable launch vehicle, the Space Shuttle seemed the first concrete step towards achieving those distant goals. The first Shuttle was even named *Enterprise*, after the spaceship on the popular *Star Trek* television series.

The possibility of being able to launch 30,000 kilograms (65,000 pounds) of Shuttle payload into orbit many times

Related Flight series filmstrips: *Satellites; Social Impact of Flight;* and *Great Spacecraft and their Accomplishments* (see back cover).

per year meant that a large amount of material could be moved into Earth orbit. During the mid-1970s the concept of *space industrialization* emerged to define those activities that would produce goods and services from operations conducted in space.

**Space Manufacturing**

The near-Earth space environment offers a virtual absence of gravity, extremely high vacuum, a continuous and abundant supply of solar energy, and the availability of millions of kilograms of raw material from the lunar surface and nearby asteroids. Certain materials—notably special metals and high-quality crystals—could be manufactured more easily in space than on Earth, where the costs of energy and maintaining a space-like vacuum are high. Moreover, manufacturing processes that require reduced gravity or control of contamination could be routine in space.

**Solar Power Satellites**

Solar energy not only could be collected and used in space, but also could be converted to microwave radiation and broadcast to stations on Earth, where it would be converted to electricity (see "Solar Power Satellites," January-February 1980 *Air & Space*). The near-zero gravity of Earth orbit would allow the construction of giant solar collectors that would not have to support their own weight, as they would on Earth. These solar collectors would orbit in constant, intense sunshine high above the clouds and atmosphere, in near-permanent daylight.

A variety of studies indicated that materials produced in space for delivery to Earth initially would cost a great deal. These materials would, therefore, have to be worth a great deal. But the solar power satellite would be self-supporting because, once it was working, operating it would be very inexpensive. It soon became clear that the solar power satellite would be a primary driving force behind space industrialization.

**Remote Sensing and Communications**

Services produced by space industrialization would expand and enhance services already realized through space exploration. For example, advanced remote sensing satellites would continue to monitor the Earth's crops, weather, oceans, and pollution (see "Weather Satellites," Fall 1980 *Air & Space*).

Communications satellites, which could be made very powerful through large solar collecting arrays, would bring about a revolution in communications. Until the era of the Space Shuttle, the cost of launching satellites has been so exorbitant that the satellites have had to be comparatively small, requiring ground receivers to be comparatively large. If a large, powerful satellite were placed in space, then ground transmitters and receivers could be made smaller. (This concept is called "complexity inversion.") If the satellite were large enough, the ground receiver would only need to be as big as a wrist radio. With a small rooftop antenna, a small receiver could tune in to the satellite directly, without the need for cable or existing line-of-sight broadcasting systems. The satellites themselves would carry perhaps as many as 1000 video channels.

Even 1000 channels probably would be saturated rapidly by many users. Businesses might use extensive teleconferencing to save on travel costs. Universities could distribute large quantities of televised courseware. A large volume of cultural, educational, and special programming, such as captioned programs for the hearing-impaired, could be offered simultaneously all over the world. Many of these channels likely would be available not only to government agencies and giant communications corporations, but also to private entrepeneurs eager to create and sell their own educational programs.

Other more exotic space-based services might improve the quality of terrestrial life. Large orbiting reflectors called *lunettas* could beam reflected sunlight into cities at night, reducing power requirements for lighting while making cities safer. Similar orbiting reflectors called *solettas* could focus more intense beams of sunlight on agricultural areas to increase growing seasons, extend working hours during harvests, and provide near-daylight conditions for other purposes.

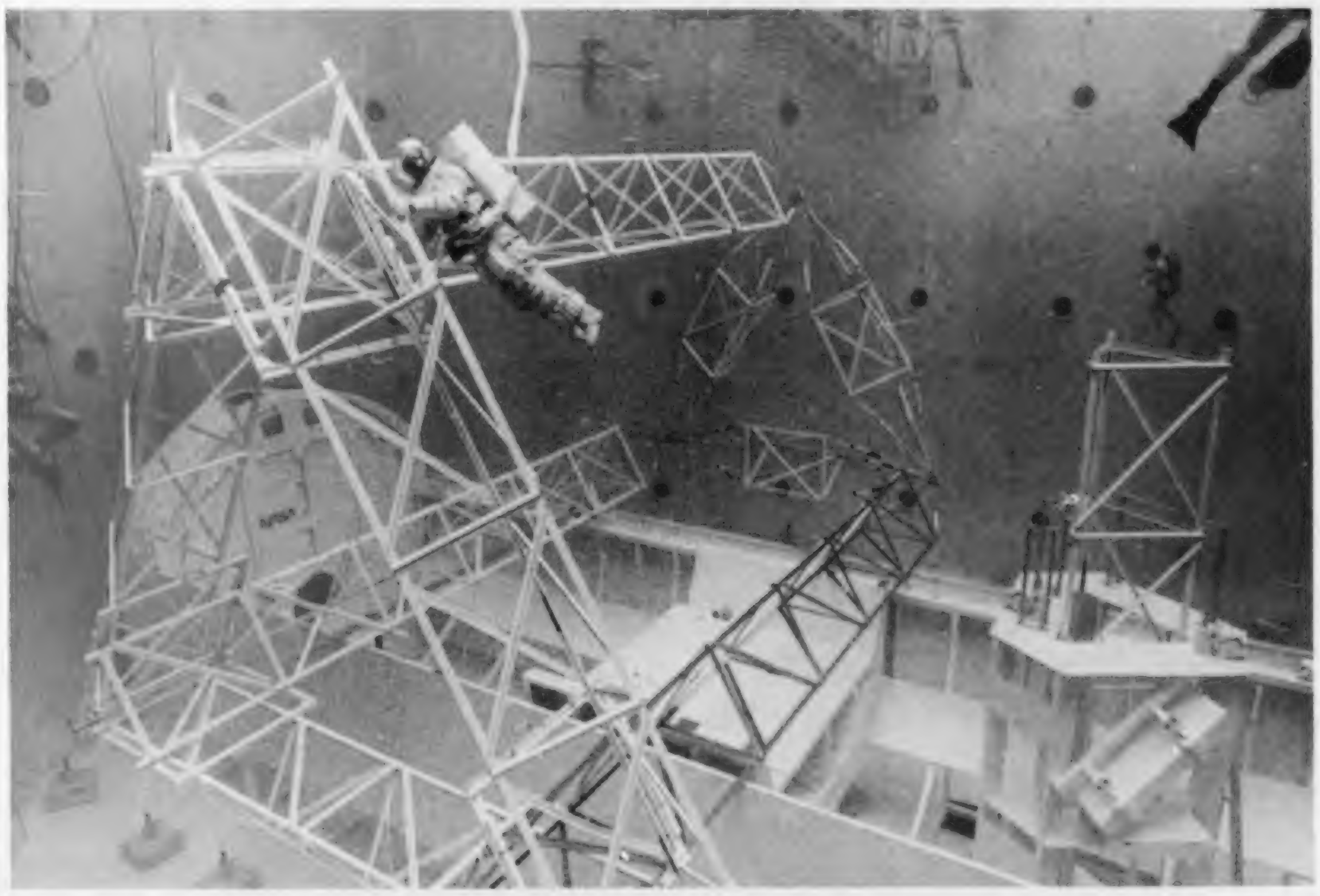
Unlike our limited planet, the space environment could easily absorb the unwanted by-products of manufacturing and processing facilities. Particle pollutants would be scattered harmlessly in the vastness of space. Similarly, the limitless capacity of space to absorb energy would allow heat-intensive processes to be carried out in space, reducing thermal pollution on Earth.

The success of space industrialization will rely heavily on the Space Shuttle and a following generation of Heavy Load Launch Vehicles. However, modest remote sensing and communications services—and some space manufacturing—still can be accomplished with expendable boosters and more modernized spacecraft.

Space industrialization may well be the industrial revolution of the 21st Century, and a turning point in the evolution of civilization. Then again, it may not. Predicting the future is an inaccurate science at best.

One thing about space industrialization already is certain. The *potential* of space industrialization suggests that in space, the "limits to growth" theory might not apply. This possibility offers an expansive and optimistic hope for the future as we enter the 1980s.

*Below: Using beams spun from spools of flat aluminum by an automated beam builder, a space-suited engineer assembles a triangular prism in "weightless" conditions underwater. Someday astronauts may use such a beam machine carried aboard the Space Shuttle to assemble large structures in Earth orbit. In this test, the engineer is taking beams from a simulated beam machine located in a Shuttle cargo bay mockup (visible at right) and assembling the beams outside the bay. This test is one of many being conducted in NASA's 5.5 million-liter (1.3 million-gallon) Neutral Buoyancy Simulator to explore space construction technology.*



# U.S. WOMEN IN AVIATION: THE 1930s

by Claudia M. Oakes
Assistant Curator
Department of Aeronautics, NASM

The 1920s and 1930s are known as the "golden age" of aviation, a time when great air races made headlines and air travel grew into a major transportation industry. Women played important and active roles in promoting aviation to the public during this period.

## Airlines Hire Women

Commercial air travel had begun before World War I. However, flying was not the most comfortable form of transportation in its infancy, and many people were apprehensive about traveling by airplane. Routes were often long, with frequent stops. Copilots did double duty. In the cockpit, they helped the pilot fly the plane. In the passenger cabin, they served meals bought from local restaurants before takeoff, answered questions, calmed nerves, and helped passengers who felt ill.

Early in 1930, Ellen Church, a registered nurse, visited the Boeing Air Transport office in San Francisco to discuss with the district manager her desire to become a pilot. Although she did not obtain a pilot position, Ms. Church did convince Boeing that hiring women as flight attendants would not only free copilots for their regular duties, but also would be a good way to show people that flying was safe. Thus on May 15, 1930, the first group of eight stewardesses began service from Chicago in a Boeing 80A Transport, westbound on the exhausting 20-hour, 13-stop route to San Francisco.

The original requirements for stewardesses were that they be single, registered nurses, not more than 25 years old, weigh not more than 115 pounds, and not be more than 5 feet 4 inches tall. The first stewardesses were paid $125 per month for 100 hours of flying. In addition to serving passengers, they assisted in refueling the aircraft, transferring baggage, and mopping the cabin floors. Other airlines quickly followed Boeing Air Transport's lead, and stewardesses became an integral part of the air transportation industry.

On December 31, 1934, Helen Richey achieved another airline "first" for women as she landed a Central Airlines Ford Tri-motor in snow flurries at Detroit City Airport. What made this particular flight other than routine was that Helen Richey had become the first woman in the United States to pilot a commercial airliner on a regularly scheduled flight.

Because of pressure from the pilots' union and the Department of Commerce, Helen Richey resigned from Central Airlines in 1935. But her flying career was far from over. Throughout the 1930s she continued to fly as a racing and aerobatic pilot and flight instructor.

## Air Racing

Air racing was one form of aviation that was particularly visible to the public. Women had had their own races, the first major one being the 1929 National Women's Air Derby from Santa Monica, California to Cleveland, Ohio (see Fall 1980 *Air & Space*, pages 14-15). However, not until 1935 were women allowed to enter one of the most prestigious competitions, the annual transcontinental Bendix Race; that year, Amelia Earhart finished an impressive fifth in the Bendix Race.

The next year, however, women proved they were competitors to be reckoned with. Louise Thaden and Blanche Noyes won the 1936 Bendix Race in their Beechcraft Staggerwing. Their flying time from New York to Los Angeles was 14 hours, 55 minutes, and 1 second, almost an hour faster than that of the second-place finisher, Laura Ingalls.

Louise Thaden already had established a name for herself in aviation, having won the 1929 National Women's Air Derby and having set several speed and distance records. Between August 14 and 22, 1932, she and Frances Marsalis established a flight duration record for women of 196 hours and 5 minutes.

## Record Flights

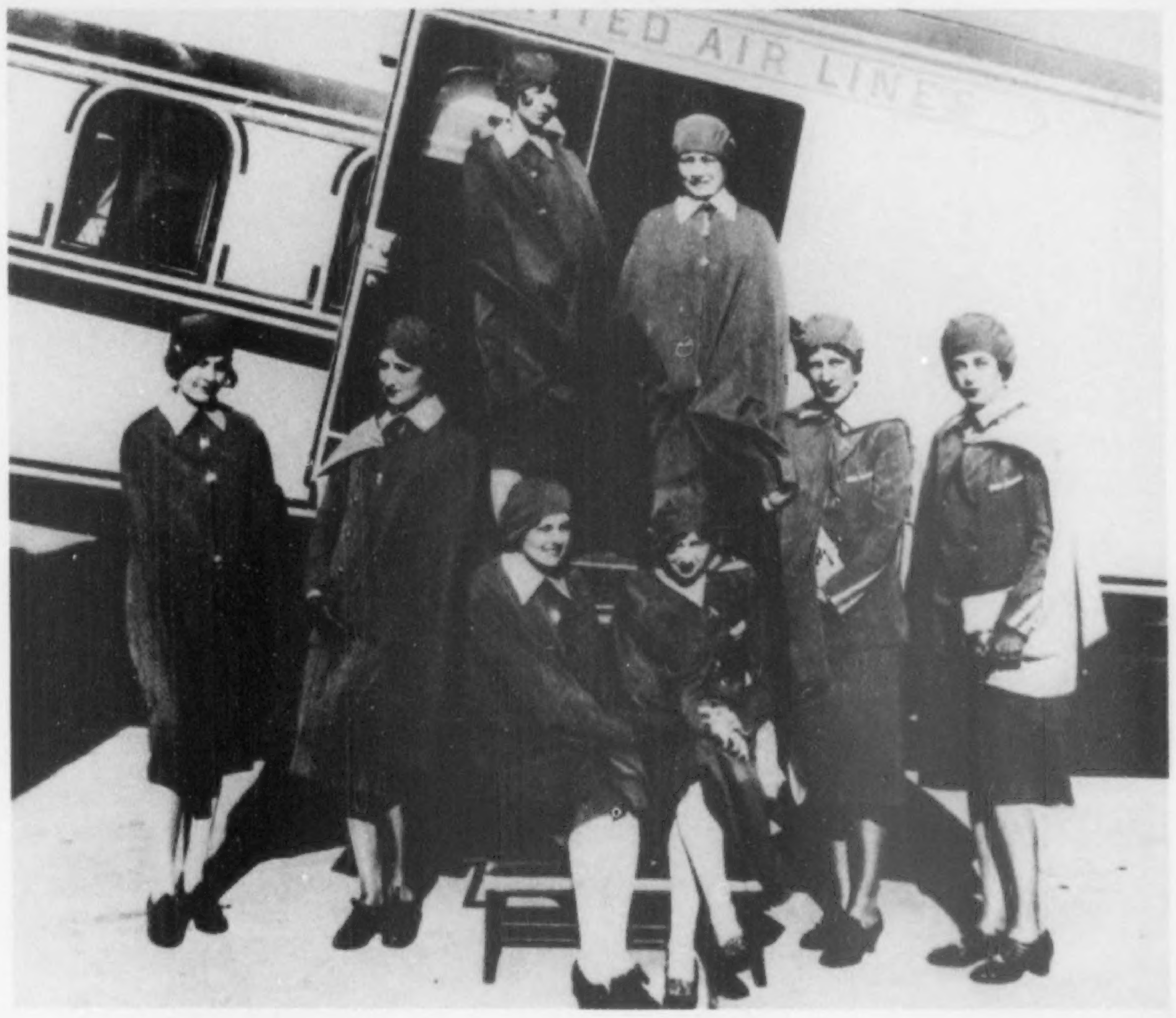
Perhaps the best-known of the many women who flew in the 1930s were Jacqueline Cochran and Amelia Earhart.

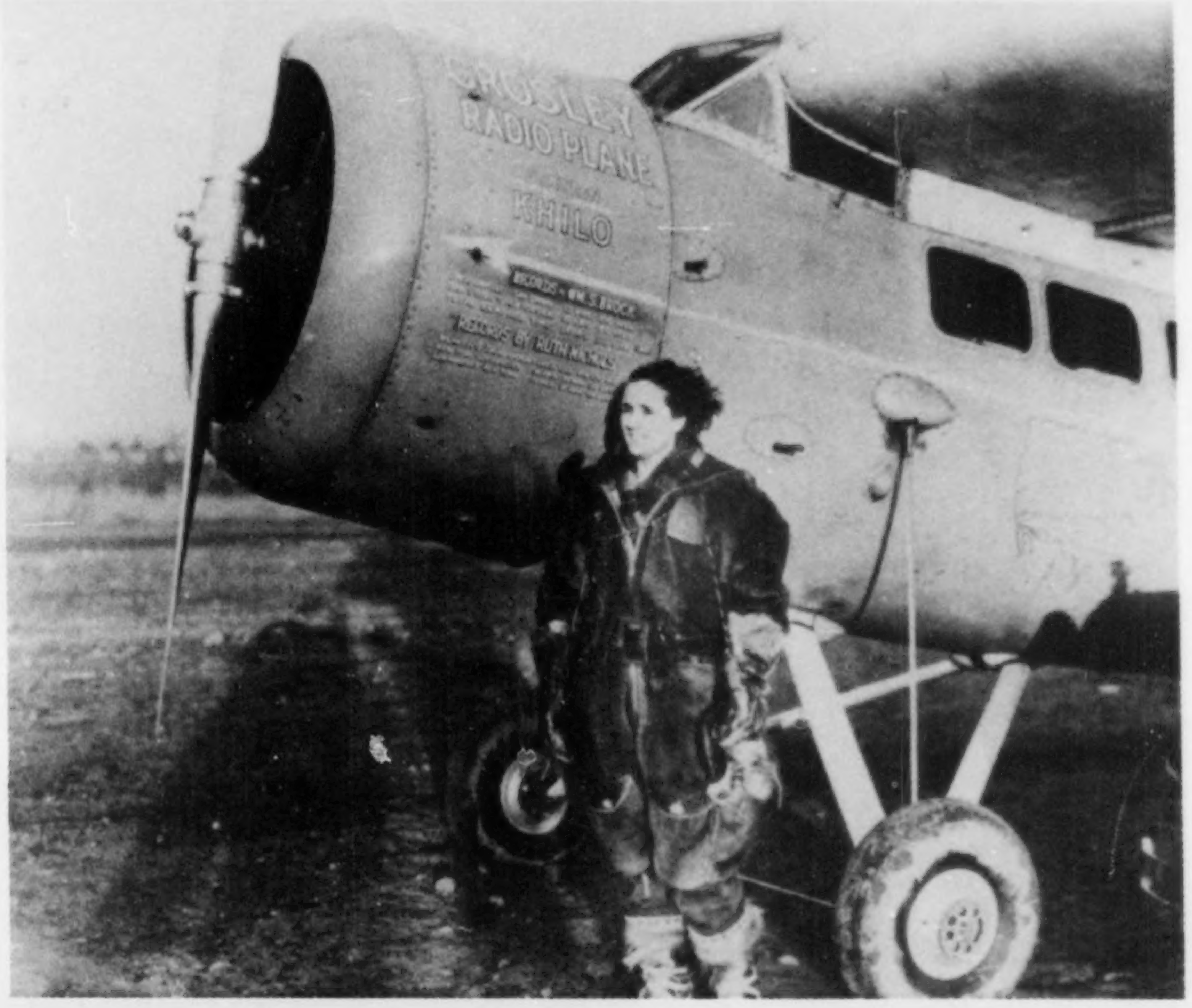
Jacqueline Cochran received her private pilot's license in 1932 and her air transport pilot's license the following year. She immediately began establishing and breaking a long list of speed records—not only women's records, but absolute records as well. On March 24, 1939, Ms. Cochran flew a Beechcraft to a national altitude record of 9159.98 meters (30,052.43 feet) over Palm Springs, California. On August 8 of that year, at Pittsburgh, she made the first "blind" landing (i.e., solely by reference to instruments) by a woman.

Before Amelia Earhart disappeared while attempting a round-the-world flight in 1937, she became the leading female figure of the decade in aviation. She wrote numerous magazine articles, gave many lectures promoting aeronautics and air travel, and did much to boost the fledgling airline industry. She also joined the staff of Purdue University.

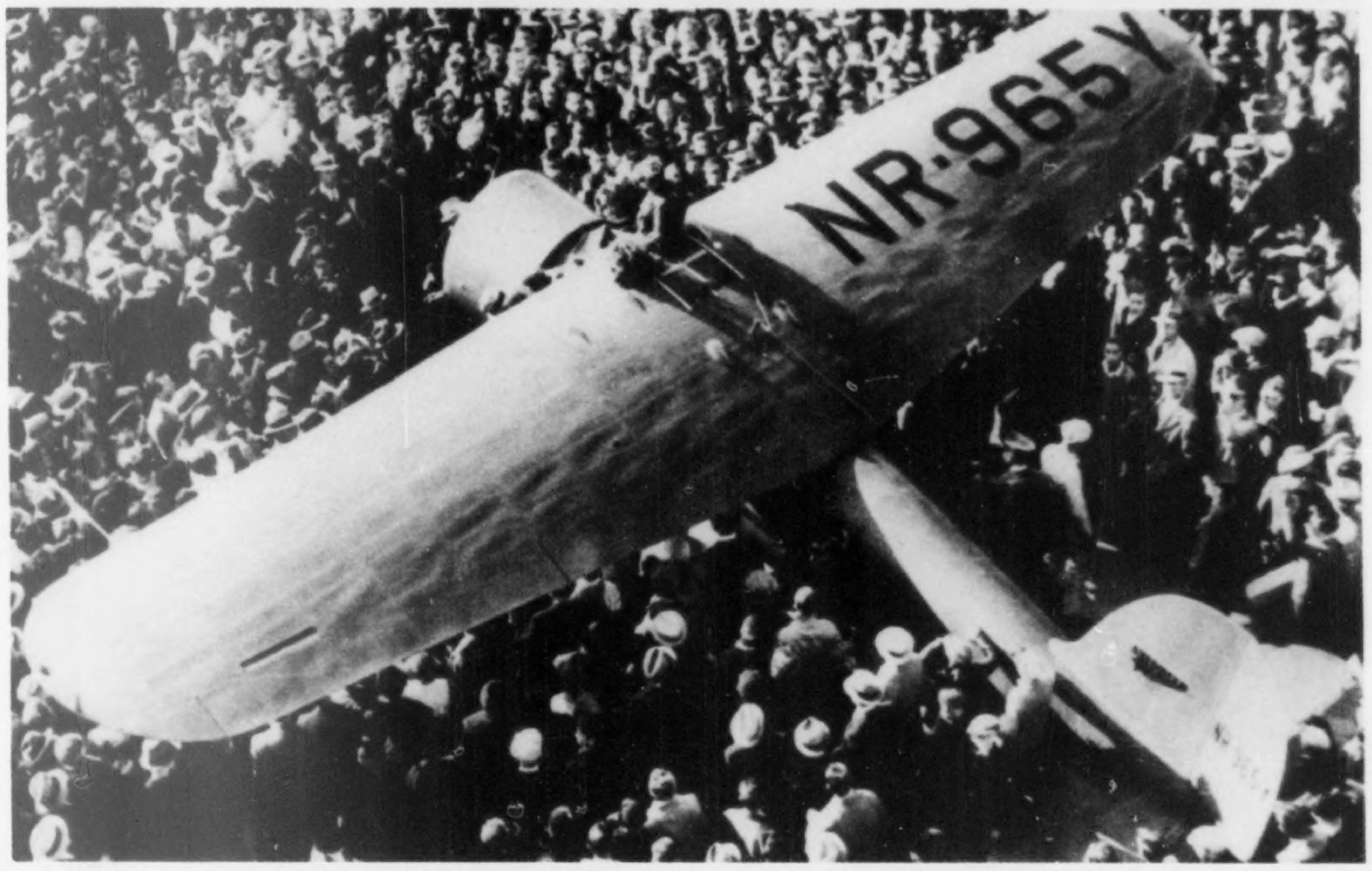
But Ms. Earhart is best remembered for her record flights, including the first solo transatlantic flight by a woman (May 20-21, 1932), five years to the day after Lindbergh's first solo crossing; first solo U.S. transcontinental flight by a woman (August 24-25, 1932); and first flight ever between Hawaii and the U.S. mainland (January 11-12, 1935). The bright red Lockheed Vega 5B that Ms. Earhart flew on her transatlantic and transcontinental flights is on display in NASM's Pioneers of Flight gallery.

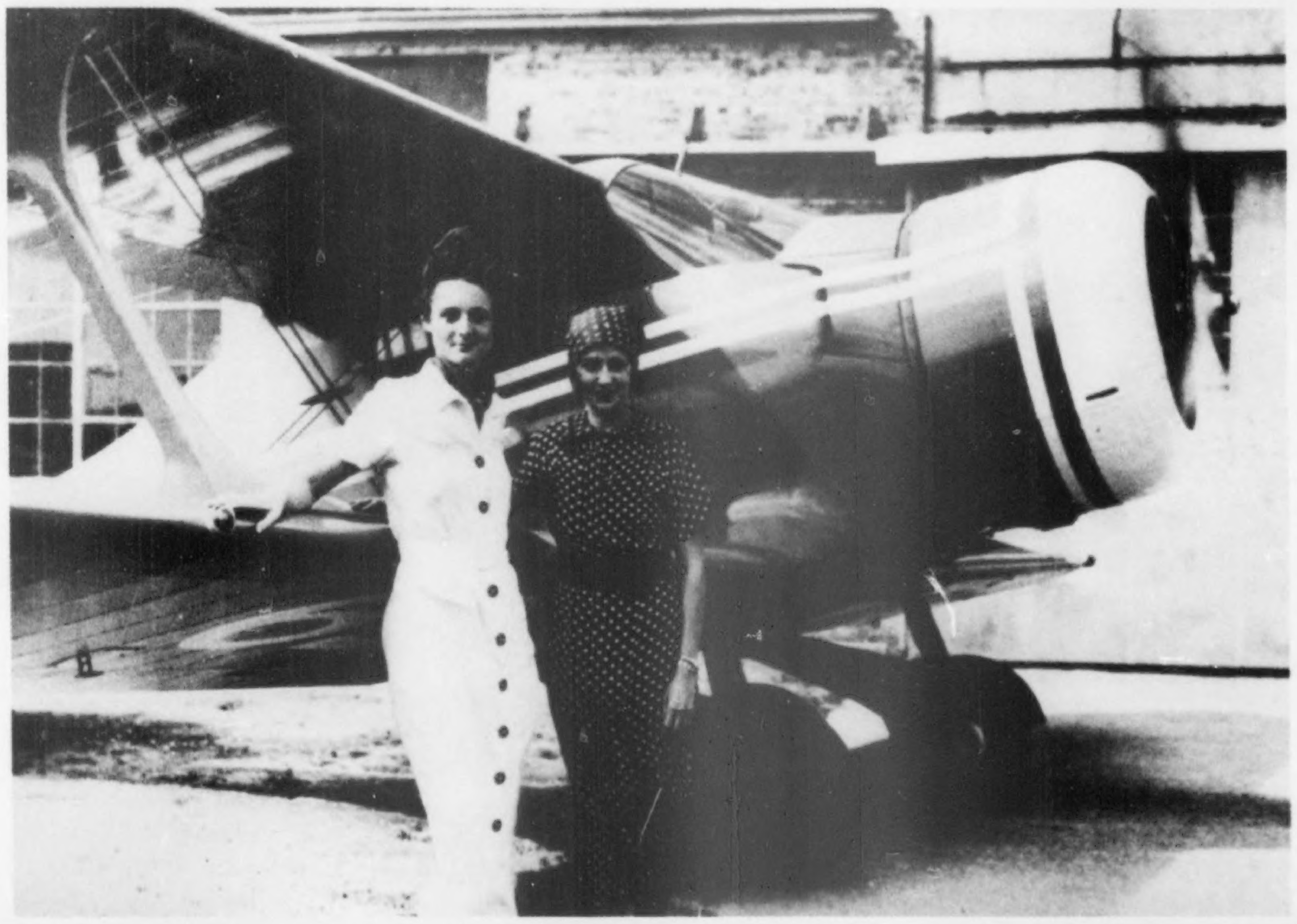
The "golden age" of aviation came to an abrupt end with the outbreak of World War II. An article in the next issue of *Air & Space* will describe how, unlike their predecessors during World War I, U.S. women pilots in the 1940s were able to play an active role in their country's war effort during that second world conflict.





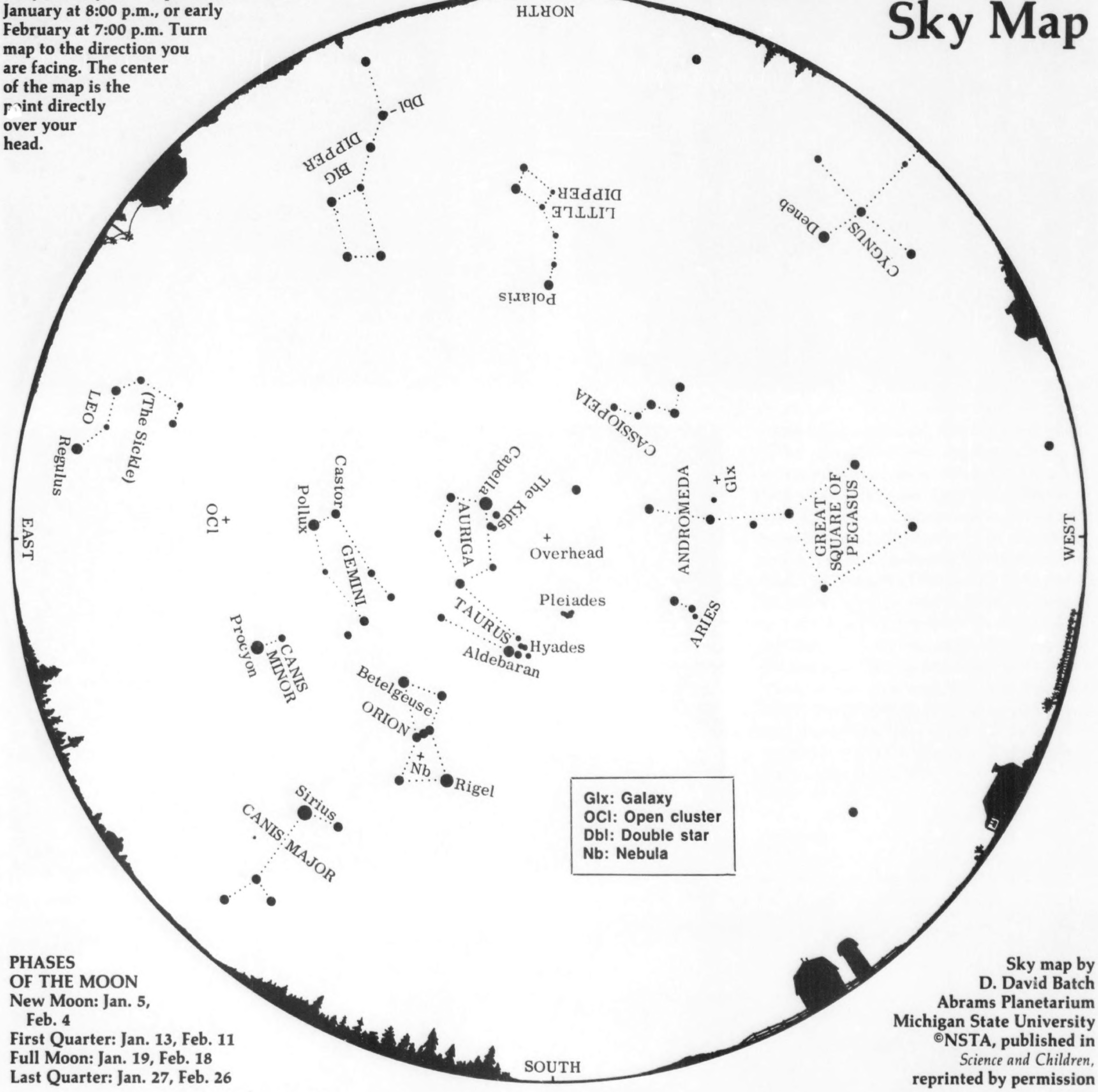
*Above left: The world's first eight stewardesses, all nurses, began work on May 15, 1930. Ellen Church, who was responsible for getting them hired, is at upper left. Above right: Ruth Nichols stands beside the Lockheed Vega, supplied to her by the Crosley Radio Corporation, in which she set a 1931 women's altitude record of 8757.5 meters (28,732 feet). Right: Amelia Earhart and her Lockheed Vega are surrounded by crowds at Oakland (California) Airport after her 1935 flight from Hawaii to the U.S. mainland. Below left: Louise Thaden (white dress) and Blanche Noyes pose beside the Beechcraft Staggerwing in which they won the 1936 Bendix Race. Below right: William Bendix congratulates Jacqueline Cochran on winning the 1938 Bendix Race.*





# January-February Sky Map

**This circle represents the night sky as it appears in late December at 10:00 p.m., early January at 9:00 p.m., late January at 8:00 p.m., or early February at 7:00 p.m. Turn map to the direction you are facing. The center of the map is the point directly over your head.**


NORTH
SOUTH
EAST
WEST
Dbl
BIG DIPPER
LITTLE DIPPER
Polaris
CYGNUS
Deneb
LEO
(The Sickle)
Regulus
OCl
Castor
Pollux
GEMINI
Capella
The Kids
AURIGA
Overhead
CASSIOPEIA
ANDROMEDA
Glx
GREAT SQUARE OF PEGASUS
Pleiades
TAURUS
Hyades
Aldebaran
ARIES
Procyon
CANIS MINOR
Betelgeuse
ORION
Nb
Rigel
Sirius
CANIS MAJOR
Glx: Galaxy
OCl: Open cluster
Dbl: Double star
Nb: Nebula

**PHASES OF THE MOON**
**New Moon: Jan. 5, Feb. 4**
**First Quarter: Jan. 13, Feb. 11**
**Full Moon: Jan. 19, Feb. 18**
**Last Quarter: Jan. 27, Feb. 26**

**Sky map by**
**D. David Batch**
**Abrams Planetarium**
**Michigan State University**
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**by T. H. Callen II**
**Production Specialist**
**Albert Einstein Spacearium, NASM**

One of the most prominent star clusters easily visible in the winter sky is the Hyades cluster, the "V" of stars marking the face of the zodiacal constellation Taurus (the Bull). The ancient Greeks believed that the Hyades forecast rainy weather, because they became visible in the sky during the Fall, a rainy season in Greece. In Greek mythology, the Hyades were half-sisters of the Pleiades, another star cluster easily seen in Taurus.

Let's make a simple comparison between these two galactic clusters which, being in the same part of the sky, can be compared easily with the naked eye. The Hyades and Pleiades clusters extend across approximately 7° and 2° of the observer's field of vision respectively. Thus they are said to have *apparent diameters* of about 7° and 2°. (The full Moon has an apparent diameter of ½°.) A cluster with a large apparent diameter could be a nearby, closely grouped cluster, or a faraway, spread-out group.

Modern astronomers know the Hyades to be an open, or galactic, star cluster, the closest known to the Sun. The distance to the Hyades is about 130 light years (one light year equals $9.46 \times 10^{12}$ kilometers, or $5.88 \times 10^{12}$ miles). The Pleiades are about 410 light years from Earth, or about three times more distant than the Hyades. The Pleiades cluster appears only one-third as large as the Hyades cluster in the night sky. Thus the parts of these two clusters visible to the unaided eye must have approximately the same real diameters.

For more on star clusters, see "Families of Stars," pages 10-12.

# OUTREACH

## by Kerry M. Joëls
## Chief, Education Services Division

When most people think of the future of education, they tend to think of the technology that will emerge to help transfer culture and knowledge to succeeding generations. Unquestionably, technology will have a major impact. The handheld calculator is a classic example of this impact.

But what will education be like in the future, barring an unforeseen wonder learning drug? The processes of education will probably continue to be permutations and combinations of present educational techniques. The subject matter, however, may differ considerably. The curriculum for the future may involve an integration of skills and an emphasis on higher orders of cognitive learning. It may not be sufficient in a complex society to make decisions based on impulse and habit.

The potential consequences of the industrialization of space are so vast that they could permanently alter not only the way in which we think about our planet but the way in which we think about our civilization and its limitations. The development of curricular models that teach logic, synthesis, evaluation, inquiry, and other skills becomes increasingly important.

Even more important is the fact that a larger segment of the population than ever before is using the school system. This means that the basic skills as we define them must be taught to a larger group of people.

Another difficulty is the rising expectations of humanity as a whole. If our technologies and political systems fail to cope with the rising aspirations of humanity, extreme social problems may result. Then the formal education system, no longer a stepping-stone to meeting these expectations, would be not only severely criticized but, perhaps, also dismantled.

Students will probably always meet with a mentor or teacher to acquire information, values, and skills. The unfolding of the next 25-50 years of human history may determine whether that information concerns how to design a city in space, or how to maintain the cutting edge of a hunting knife.

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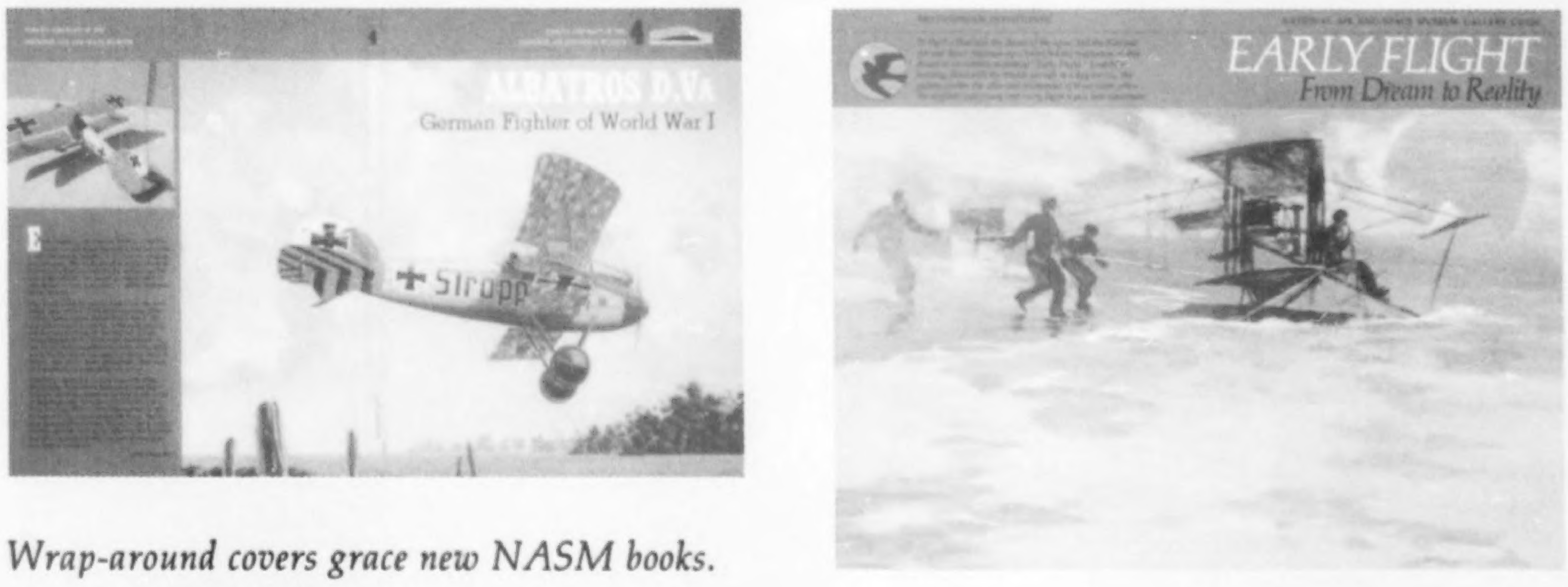

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